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THE EFFICIENCY OF SOIL CONSERVATION INVESTMENTS AND ECONOMIC IMPLICATIONS FOR CHANGE

Iowa State University  Ph.D.  1983

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The efficiency of soil conservation investments and economic implications for change

by

Dennis LaMar Nef

A Dissertation Submitted to the Graduate Faculty in Partial Fulfillment of the Requirements for the Degree of DOCTOR OF PHILOSOPHY

Department: Economics
    Major: Agricultural Economics

Approved:

Signature was redacted for privacy.

Charge of Major Work

Signature was redacted for privacy.

For the Graduate College

Iowa State University
    Ames, Iowa

1983
## TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Conservation Rationale</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Objectives</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Organization</td>
<td>8</td>
</tr>
<tr>
<td>II</td>
<td>THE SOIL RESOURCE</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Soil Classification</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Changes in the Soil Resource</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Formation</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Erosion</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Trend</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>Productivity Effects</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Soil Conservation</td>
<td>25</td>
</tr>
<tr>
<td>III</td>
<td>ECONOMIC EFFICIENCY AND SOCIAL CHOICE</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>Economics and the Social Optima</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>Production efficiency</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>Consumption efficiency</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Economy wide efficiency</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>Problems with the Social Optima</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Efficiency in Policy Analysis</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Government, Market Failure, and the Soil Resource</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>Undervaluation</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>Decision maker failure</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>Externalities</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>Program Review and Evaluation</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>Targeting proposals</td>
<td>45</td>
</tr>
<tr>
<td>CHAPTER IV. THE ECONOMIC FRAMEWORK OF CONSERVATION</td>
<td>49</td>
<td></td>
</tr>
<tr>
<td>Analytical Problems</td>
<td>49</td>
<td></td>
</tr>
<tr>
<td>A Static Economic Model</td>
<td>51</td>
<td></td>
</tr>
<tr>
<td>An Intertemporal Economic Model</td>
<td>57</td>
<td></td>
</tr>
<tr>
<td>CHAPTER V. CONSERVATION BENEFITS: DATA, ANALYSIS, AND RESULTS</td>
<td>68</td>
<td></td>
</tr>
<tr>
<td>Data</td>
<td>68</td>
<td></td>
</tr>
<tr>
<td>Implicit Soil Prices</td>
<td>69</td>
<td></td>
</tr>
<tr>
<td>Factors affecting price</td>
<td>69</td>
<td></td>
</tr>
<tr>
<td>Estimated prices</td>
<td>72</td>
<td></td>
</tr>
<tr>
<td>Iowa</td>
<td>82</td>
<td></td>
</tr>
<tr>
<td>Corn Belt</td>
<td>84</td>
<td></td>
</tr>
<tr>
<td>Policy Implications and Limitations</td>
<td>88</td>
<td></td>
</tr>
<tr>
<td>CHAPTER VI. THE ADOPTION OF CONSERVATION PRACTICES</td>
<td>91</td>
<td></td>
</tr>
<tr>
<td>Previous Studies</td>
<td>92</td>
<td></td>
</tr>
<tr>
<td>Theoretical Basis of Adoption Models</td>
<td>96</td>
<td></td>
</tr>
<tr>
<td>Statistical methods</td>
<td>97</td>
<td></td>
</tr>
<tr>
<td>Explanatory variables</td>
<td>98</td>
<td></td>
</tr>
<tr>
<td>The Choice Among Practices</td>
<td>101</td>
<td></td>
</tr>
<tr>
<td>Policy Implications and Limitations</td>
<td>111</td>
<td></td>
</tr>
<tr>
<td>CHAPTER VII. SUMMARY AND CONCLUSIONS</td>
<td>114</td>
<td></td>
</tr>
<tr>
<td>Justification of the Research</td>
<td>114</td>
<td></td>
</tr>
<tr>
<td>The Economic Model and its Application</td>
<td>116</td>
<td></td>
</tr>
<tr>
<td>Conclusions and Future Research Efforts</td>
<td>118</td>
<td></td>
</tr>
<tr>
<td>BIBLIOGRAPHY</td>
<td>121</td>
<td></td>
</tr>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>134</td>
<td></td>
</tr>
</tbody>
</table>
LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1.</td>
<td>America's land base in 1977 (USDA, 133)</td>
<td>3</td>
</tr>
<tr>
<td>Figure 2.</td>
<td>A farmer's view of the optimal level of soil erosion</td>
<td>55</td>
</tr>
<tr>
<td>Figure 3.</td>
<td>The optimal level of soil erosion as perceived by society</td>
<td>55</td>
</tr>
</tbody>
</table>
LIST OF TABLES

Table 1. Cropland acreage, 1975, by region and capability classes (Swader, 123) 12

Table 2. Gross annual erosion on nonfederal land in the United States, 1977 (USDA, 126) 14

Table 3. Annual sheet and rill erosion on cropland and the amount of erosion in excess of 5 tons per acre, by erosion rate, 1977 (USDA, 129) 17

Table 4. Erosion from cropland in the United States in 1977 (USDA, 126) 18

Table 5. Expected changes in yields of selected crops in selected areas if 1977 erosion rates continue for the next 50 years (Swader, 123) 22

Table 6. Characteristics of major land resource areas (Austin, 7) 71

Table 7. Prepractice erosion rate groups 75

Table 8. Implicit price of a ton of soil by Major Land Resource Area and prepractice erosion rate in Iowa--1981-1982 76

Table 9. Definition of variables used in regression analysis 81

Table 10. Results of Iowa Soil Conservation price estimation 83

Table 11. Results of Corn Belt soil conservation price estimation 85

Table 12. Estimates of coefficients and t ratios 105

Table 13. Probability of adoption of soil conservation practices by region for land class and farm size combinations 109
CHAPTER I. INTRODUCTION

The proper use of natural resources has probably been a subject of debate since man's earliest days. Questions of propriety depend on values which are likely to vary by individual. One person's wise use of a particular resource may be perceived as wasteful by another. Governments were formed in part to insure that consideration of common values was not overlooked by powerful individuals or groups. Differences between societal and private values have led at times to conflict between the public and private sectors in resource management. Pigou (102) framed the dilemma over fifty years ago when he wrote:

It is the clear duty of Government, which is the trustee for unborn generations as well as for its present citizens, to watch over, and, if need be, by legislative enactment, to defend, the exhaustible natural resources of the country from rash and reckless spoliation. How far it should itself, either out of taxes, or out of state loans, or by the device of guaranteed interest, press resources into undertakings from which the business community, if left to itself, would hold aloof, is a more difficult problem. (pp. 29-30)

In determining the role of government in resource management, two major questions arise: (1) How much should government invest in the resource? and (2) Where should the funds be invested? The issues are not completely separable since the extent of government involvement will partially determine where funds are spent and the efficiency with which monies are used will affect the level of investment (Heady, 66). Although Pigou's "difficult problem" focused only on the first question, the second is not a great deal more tractable.

Current concerns regarding government investment in agricultural land revolve around the two issues of 'how much' and 'where'.
Investments in the soil resource have been defined as soil conservation (Bunce, 20). While such investments might include funding of erosion reduction practices, irrigation projects or even agricultural-related research, the subject is here restricted to include funding of erosion reduction measures only. The reasons for such investments are many and varied. Modern proponents of soil conservation seem to base their arguments on such issues as resource adequacy, deteriorating environmental quality, excessive soil loss, and slowing rates of technological change. A brief examination of these arguments provides some understanding of why governments are involved in soil conservation as well as insight into some of the more important unresolved issues related to soil resource investments.

Conservation Rationale

America has been endowed with a great deal of productive land. Although the federal government owns approximately one-third of the 2263 million acre land base, the most productive lands are predominantly privately held. Figure 1 provides a breakdown of the land base in 1977. Most of the nonfederal land is in rural settings and the majority of this rural land is classified as agricultural land. The 1361 million acres of agricultural land are supposedly all lands "currently used to produce agricultural commodities including forest products or lands that have the potential for such production" (USDA, 133, p. 21). Such a definition is not totally accurate since the classification fails to include 500 million acres of federal lands that are important contributors to timber and livestock production (Brewer and Boxley, 16).
Figure 1. America's land base in 1977 (USDA, 133)
It also does not include land in urban areas that is used for agricultural purposes (Raup, 107). While all agricultural lands are not important economically, much of the publicity related to land use and soil conservation fails to recognize this (USDA, 133; Brewer and Boxley, 16; Raup, 107).

A further division of the agricultural land class reveals 413 million acres of cropland with a potential increase from range, forest and pasture lands of 127 million acres given 1977 price relationships and technologies. Approximately 380 million acres were planted to crops in 1980—about the same as in 1949 and greater than any year in between.

Although controversy exists regarding the accuracy of this classification scheme (Fischel, 52; Raup, 107; Brewer and Boxley, 16), it is sufficient for present purposes. Note that a substantial amount of cropland is used for other than cropping purposes and that unused and potential cropland provide a degree of insurance (Crosson, 39). Nevertheless, a debate regarding the adequacy of agricultural lands that has waxed and waned for centuries continues (Crosson, 40). It provides one of the major arguments for soil conservation—without conservation, it is argued that future productivity will be excessively impaired and agricultural production will fall short of demand.

Concern for the adequacy of pure water, open spaces and natural surroundings also motivates conservation. Preservation of adequate agricultural lands to meet production goals will be irrelevant if concern for the adequacy of these other resources is the issue. The fact that conservation may not be indicated on productivity grounds does not
negate the need on the basis of environmental quality and vice versa.

Several other issues contribute to the present concern for soil conservation. Since the early 1970s, agricultural exports have become increasingly important to the United States. Crop shortfalls abroad coupled with rising incomes and Soviet desires to upgrade diets diminished U.S. grain surpluses and reduced the need for governmental price supports. The balance of payments problems caused by increased oil prices were offset largely by agriculture. The government found itself advocating fencerow to fencerow planting. Marginal lands were put under more intensive cultivation to meet the increased demand. In the rush to expand production, some felt the soil resource was being used unwise-ly (being exported with the crops) and more widespread use of conserva-
tion measures was needed (Timmons and Amos, 125). However, a world-
wide economic recession in the early 1980s dampened demand. This,
coupled with recent record harvests, led to a return to supply manage-
ment by government. Acreage diversion programs (paid diversion, payment
in kind) are expected to substantially decrease cultivation of marginal
and other lands in 1983. Although marginal lands are being retired,
concerns regarding the exportation of soil remain. It is unclear whether
the present is an aberration from the pattern of the 1970s or a new trend.

There is still a concern, even in the absence of increased exports,
that land use practices of modern agriculture lead to excessive erosion
(Congress of the U.S., 34). The large equipment used compacts the soil
and has led farmers to remove fences, windbreaks, terraces and other
conservation structures. The resulting long straight rows coupled with
limited cropping changes (monocultures) exacerbate soil loss.

In addition to the issues of resource adequacy and the proper use of soil, doubts are raised regarding future rates of technological change in agriculture. Changes in productivity and crop yields due to hybrids, better equipment, and managerial skills have offset reductions in productivity due to erosion in the past (see Walker and Young (138) for a dissenting view). Whether this will continue to be the case is, of course, unknown. It is argued that productivity grew at slower rates from 1972-1979 than from 1950-1972 (Crosson, 40). At the same time, it is argued that there is no statistical evidence of a decline in productivity growth for the 1970-1979 period (Heady, 64). The growth rate is important. Crosson (40) found that estimates of the amount of land needed to meet projected demands for grain and soybeans in 2005 varied greatly depending on the rate of growth in yields. Growth at a 2% annual rate would require 237 million acres while 310 million acres would be required at 1%. An argument for either rate can be made though more weight is usually given to the lower number in projections.

It can be argued then that investments in the soil resource (or conservation) are justified to maintain its productive capacity and insure the adequacy of other resources. The appropriate level of investment requires a determination of the amount of the resource to be used now and how much to leave for future use—Pigou's problem posed earlier. It also depends on the efficiency with which such investments preserve the various resources. The costs of soil investments are usually known (at least approximately since opportunity costs may be
hard to define). The benefits are less quantifiable. Often, the benefits are assumed to be very large so that conservation is promoted at any cost. It is likely, however, that costs exceed benefits beyond some level of conservation. This implies that an optimal amount of conservation exists. It is sometimes argued that farmers fail to supply such an optimal quantity. If such is the case, the government can expect to be called upon to make up the deficiency.

Objectives

The major issues associated with soil conservation involve the determination of the role of government, determination of the optimal amount of conservation, determination of efficient practices, and accurate measurement of conservation benefits. These areas of inquiry are pursued in this research. The specific objectives of the study are:

1. To explain why governmental investment in soil conservation may be desired;
2. To develop an economic model of soil use that can provide optimal decision rules for producers and policy makers;
3. To estimate the benefits of soil conservation from both private and social points of view for different soils and locations in Iowa and the Corn Belt;
4. To determine the effect of soil characteristics on the decision to adopt a particular conservation practice;
5. To derive the implications for improving government soil conservation policy arising from objectives (3) and (4).
While arguments for government conservation efforts will hopefully be clarified, the determination of conservation benefits may be the most significant result of the research. The process used places a value on the soil resource. Since measures of both private and social values are obtained, valuation of externalities is also performed. Current policy debates are stymied by a lack of such information. A knowledge of the value or price of particular soils will allow researchers to quantify benefits of soil-related research and thereby determine project priorities. Such prices could also aid in efficient policy development and program management.

The analysis should also show how results of government soil conservation programs have changed over time and whether such changes have or have not been beneficial. Such information can greatly aid future expenditures on soil conservation by increasing the efficiency with which such funds are used. The ability to predict the probability of adoption of a practice by a farmer on the basis of land attributes would also be useful in improving government policy.

Organization

Chapter II provides an overview of the soil resource—how it is described, how it changes, the state of knowledge regarding rates of change, and the effects of such changes on productivity. The concept of soil conservation is also discussed.

Chapter III briefly traces the theory of welfare economics. The economic basis for social choice using efficiency criteria is discussed
and applied to soil use. Possible justifications for government investment in the soil resource are also discussed. Past conservation programs are reviewed and present policy proposals are examined.

In Chapter IV, a micro theoretical model is developed to examine soil resource allocation. Optimal decision rules are derived and the implications for soil values given soil-saving investments are presented. It is shown that information necessary to value soils can be obtained using the assumption of rationality and currently available data.

Chapter V describes the database, the data analysis and the results of the soil valuation process. Statistical tests are performed to determine sources of significant differences in conservation benefits. The policy implications of the results are also presented.

The effect of soil characteristics on soil conservation practice adoption is modeled in Chapter VI. A multinomial logit procedure is used to estimate adoption rates of four conservation practices. The results and their policy relevance are discussed.

Chapter VI contains a brief summary of the research and conclusions.
CHAPTER II. THE SOIL RESOURCE

Resources are often classified as being either renewable or non-renewable. Soil is not easily placed in such a classification system since it is actually a composite of many other resources (Timmons, 124; Schumm and Harvey, 115; Ciriacy-Wantrup, 26). This composite includes nutrients, other chemicals, water, many species of plants and animals, site and other physical conditions. The use of the composite resource may be measured in several ways. The displacement of the resource may be viewed as a use since the same physical unit is no longer available for other purposes. Alternatively, use may also be measured in terms of the flow of benefits or the foreclosing of such a flow (opportunity costs associated with paving over, building on, or flooding of the soil).

The flow of agricultural benefits from a given plot of soil is referred to as soil productivity and is affected not only by water, nutrients, organic matter, other chemical properties and physical properties but also by climate, management, equipment and the genetic potential of crops grown. Soils and/or soil productivity are renewable in the sense that soils form over time and can sustain production for many years. Productivity may be compensated for to the extent that technology increases the yields obtainable from a given plot. Productivity is non-renewable for a given soil if erosion or usage exhausts or permanently halts the productive potential. Conservation may refer either to the saving of the soil or the soil's productivity. This chapter briefly reviews the state of knowledge regarding soil, rates of change
-associated with soils and soil productivity, and alternative definitions of conservation.

Soil Classification

A soil's suitability for agricultural purposes has been expressed in terms of capability classes and subclasses based on limitations to the production of crops. These classes are:

Class I: Soils with few limitations restricting their use.
Class II: Soils with moderate limitations restricting their use.
Class III: Soils with severe limitations restricting their use.
Class IV: Soils with very severe limitations restricting their use.
Class V: Soils that are not likely to erode but that have other limitations, which are impractical to remove, restricting their use.
Class VI: Soils with severe limitations that make them generally unsuitable for cultivation.
Class VII: Soils with very severe limitations that make them unsuitable for cultivation.
Class VIII: Soils and landforms with limitations that nearly preclude their use for commercial crop production.

The distribution of cropland by region and land capability class is shown in Table 1.
Table 1. Cropland acreage, 1975, by region and capability classes (Swader, 123)

<table>
<thead>
<tr>
<th>Farm production region</th>
<th>Millions of acres</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total crop-</td>
</tr>
<tr>
<td></td>
<td>land Acres</td>
</tr>
<tr>
<td>Northeast</td>
<td>17.3</td>
</tr>
<tr>
<td>Lake States</td>
<td>44.2</td>
</tr>
<tr>
<td>Corn Belt</td>
<td>86.3</td>
</tr>
<tr>
<td>Northern Plains</td>
<td>91.2</td>
</tr>
<tr>
<td>Appalachian</td>
<td>20.7</td>
</tr>
<tr>
<td>Southeast</td>
<td>16.3</td>
</tr>
<tr>
<td>Delta States</td>
<td>20.5</td>
</tr>
<tr>
<td>Southern Plains</td>
<td>40.9</td>
</tr>
<tr>
<td>Mountain</td>
<td>40.1</td>
</tr>
<tr>
<td>Pacific</td>
<td>22.1</td>
</tr>
<tr>
<td>AK, HK, PR, VI</td>
<td>0.7</td>
</tr>
</tbody>
</table>

440.5 344.4 73.0 16.4

Changes in the Soil Resource

Changes in the soil resource alter both the quantity and the quality of the remaining soil. There is agreement that soil formation and erosion occur naturally and that man can and has affected both (Hall et al., 59). However, the rates at which such changes occur and their effects are subjects of considerable dispute.

Formation

Soil genesis or the formation of new soil occurs through the process of weathering of parent rock and/or the renewal of existing soil through accumulation, deposition, or structural changes (Hall et al., 59). Formation rates of .15, 1.5 and even 5 tons per acre per year are cited in the literature but are not founded on a rigorous scientific base.
(Pimental et al., 103; Hall et al., 59). Actual rates depend on the parent material and other factors affecting use. Normal agricultural practices are thought to form soil at .5 to 1.5 tons per acre per year (Schumm and Harvey, 115). Although topsoil may form at these rates, there is increasing concern that subsoil formation is much slower (Congress of the U.S., 34).

Erosion

Soil erosion or the wearing away of the soil surface can be classified as either wind, sheet and rill, gully or streambank erosion depending on the nature of the erosive process. Wind erosion is important in the Great Plains and may account for as much as 1/4 of all erosion nationwide (Pimental et al., 103). However, sheet and rill erosion is responsible for the majority of soil loss. Sheet erosion removes a thin layer of soil through rainfall and runoff action. Rill erosion occurs when runoff water creates small channels and soil from the channel beds is removed. These 'rills' are smoothed in normal tillage operations. When the channels impede normal operations and can no longer be covered, gully erosion takes place. Streambank erosion is usually not under a farmer's control and will not be considered below. Estimates of the amount of erosion caused by these processes are shown in Table 2.

Measurement of erosion

Measurement of erosion is necessary to determine its effects and to chart the progress of erosion reduction efforts. The Universal Soil Loss Equation (USLE) has been developed to predict sheet and rill erosion based on soil characteristics and
Table 2. Gross annual erosion on nonfederal land in the United States, 1977 (USDA, 126)

<table>
<thead>
<tr>
<th>Land use</th>
<th>Sheet, rill, and wind erosion on agricultural land</th>
<th>Total acre-age in erosion</th>
<th>Total acre-age in erosion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;2 tons/acre</td>
<td>2-5 tons/acre</td>
<td>5-13.9 tons/acre</td>
</tr>
<tr>
<td>Cropland</td>
<td>158.6</td>
<td>113.6</td>
<td>93.1</td>
</tr>
<tr>
<td>Pastureland</td>
<td>105.0</td>
<td>14.0</td>
<td>9.5</td>
</tr>
<tr>
<td>Forest land</td>
<td>327.0</td>
<td>26.0</td>
<td>11.7</td>
</tr>
<tr>
<td>Rangeland</td>
<td>283.5</td>
<td>55.5</td>
<td>40.1</td>
</tr>
<tr>
<td>Total sheet, rill, and wind erosion</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Total erosion on streambanks, gullies, roads and roadsides, and construction sites</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Total</td>
<td>874.1</td>
<td>209.1</td>
<td>154.4</td>
</tr>
</tbody>
</table>

management practices (Wischmeier and Smith, 141). The equation is:

\[ A = RKSCP \]

where each letter represents a variable.

A is the predicted average annual soil loss in tons per acre for a given area. R is a rainfall and runoff value measuring the susceptibility of the soil to erosion from moving water. K is the soil erodibility value. K-values have been determined for all soils based on soil
characteristics affecting erodibility. L is a slope length factor. Slope length is the distance from the point of origin of overland flow to the point where (a) the slope decreases and deposition begins, or (b) runoff enters a well-defined channel. The factor is the ratio of soil loss from a specific length of slope to that from the length specified for the K-value. S is a steepness of slope factor. It is the ratio of soil loss from the field slope gradient to that from a standard slope under otherwise identical conditions.

The product of \( R, K, L, \) and \( S \) is an estimate of the average gross soil loss from a tilled continuously fallow field on a given soil. Losses increase as rainfall, slope length, steepness and inherent erosivity increase. \( C \) is a cover and management factor. It is the expected ratio of soil lost from land cropped under specified conditions to that lost from continuously cultivated fallow land with identical soil, slope, and rainfall conditions. This value adjusts gross erosion for influences of crops, crop rotations, and other management considerations. \( P \) is an erosion control practice factor. It is the ratio of soil loss under a specified conservation practice to that with uphill and downhill farming operations under equivalent conditions. It adjusts gross soil loss to account for actions reducing the velocity of runoff.

Wind erosion is estimated from an equation similar to the USLE although the estimation is valid only in the Great Plains region (Skidmore and Woodruff, 118). The equation may be written as

\[
E = F(KCVL)
\]
E is the potential annual soil loss in tons per acre per year. F denotes a function. I is the soil erodibility value expressed as the average annual soil loss per acre that would occur from an isolated, level, smooth, unsheltered wide, and bare field with a noncrusted surface at Garden City, Kansas. K is the soil ridge roughness value. C is the climatic value which is based on the average wind velocity and the precipitation-evaporation index for a given location. V is the vegetative cover value which accounts for the quantity, kind, and orientation of residue. L is the unsheltered distance across a field along the prevailing wind direction.

The amount of erosion estimated to occur in the U.S. in 1977, and its distribution can be ascertained from Tables 2, 3 and 4. Table 2 shows the amount of the different types of erosion by land use and erosion rate. Table 3 shows the number of acres of cropland eroding by erosion rate and the cumulative percentage of erosion at each rate. Only sheet and rill erosion estimates are included in this table. While 77% of the nation's cropland erodes at less than 5 tons per acre per year, just under 9% erodes at rates greater than 10 tons per acre per year. However, this 9% of the cropland accounts for over half of all sheet and rill erosion. Table 4 presents a geographical breakdown of erosion. It is evident from data in this table that the Corn Belt, Appalachia, the Southeast and the Southern Plains have more than their share of erosion problems.

Despite the straightforward nature of the formulas and statistics, broad areas of ignorance with respect to soil loss measurement remain
Table 3. Annual sheet and rill erosion on cropland and the amount of erosion in excess of 5 tons per acre, by erosion rate, 1977 (USDA, 129)

<table>
<thead>
<tr>
<th>Annual erosion rate (tons per acre)</th>
<th>Total acres (millions)</th>
<th>Cumulative percentage of acreage</th>
<th>Total sheet and rill erosion (millions of tons)</th>
<th>Cumulative percentage of erosion in excess of 5 tons per acre (millions of tons)</th>
<th>Total erosion in excess of 5 tons per acre (millions of tons)</th>
<th>Cumulative percentage of erosion in excess of 5 tons per acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-1</td>
<td>131.6</td>
<td>31.8</td>
<td>49.2</td>
<td>2.6</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>1-2</td>
<td>74.6</td>
<td>49.8</td>
<td>110.6</td>
<td>8.3</td>
<td>0.0</td>
<td>0.0</td>
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<tr>
<td>2-3</td>
<td>51.5</td>
<td>62.3</td>
<td>127.5</td>
<td>14.9</td>
<td>0.0</td>
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<tr>
<td>3-4</td>
<td>35.9</td>
<td>71.0</td>
<td>125.0</td>
<td>21.4</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>4-5</td>
<td>26.0</td>
<td>77.3</td>
<td>116.3</td>
<td>27.4</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>5-6</td>
<td>17.6</td>
<td>81.6</td>
<td>96.2</td>
<td>32.4</td>
<td>8.2</td>
<td>0.9</td>
</tr>
<tr>
<td>6-7</td>
<td>12.6</td>
<td>84.6</td>
<td>81.8</td>
<td>36.6</td>
<td>18.6</td>
<td>2.9</td>
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<td>7-8</td>
<td>9.3</td>
<td>86.9</td>
<td>69.4</td>
<td>40.2</td>
<td>23.0</td>
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<tr>
<td>8-9</td>
<td>7.3</td>
<td>88.7</td>
<td>62.0</td>
<td>43.4</td>
<td>25.4</td>
<td>8.1</td>
</tr>
<tr>
<td>9-10</td>
<td>5.8</td>
<td>90.1</td>
<td>54.6</td>
<td>46.2</td>
<td>25.8</td>
<td>10.9</td>
</tr>
<tr>
<td>10-11</td>
<td>4.8</td>
<td>91.3</td>
<td>50.2</td>
<td>48.8</td>
<td>26.3</td>
<td>13.7</td>
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<tr>
<td>11-12</td>
<td>3.7</td>
<td>92.2</td>
<td>43.1</td>
<td>51.0</td>
<td>24.4</td>
<td>16.3</td>
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<td>12-13</td>
<td>3.0</td>
<td>92.9</td>
<td>36.9</td>
<td>52.9</td>
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<td>18.7</td>
</tr>
<tr>
<td>13-14</td>
<td>2.8</td>
<td>93.6</td>
<td>37.1</td>
<td>54.8</td>
<td>23.3</td>
<td>21.2</td>
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<tr>
<td>14-15</td>
<td>2.4</td>
<td>94.2</td>
<td>34.6</td>
<td>56.6</td>
<td>22.7</td>
<td>23.6</td>
</tr>
<tr>
<td>15-20</td>
<td>7.8</td>
<td>96.1</td>
<td>134.8</td>
<td>63.6</td>
<td>95.8</td>
<td>33.9</td>
</tr>
<tr>
<td>20-25</td>
<td>4.4</td>
<td>97.1</td>
<td>98.0</td>
<td>68.7</td>
<td>76.0</td>
<td>42.1</td>
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<tr>
<td>25-30</td>
<td>2.9</td>
<td>97.8</td>
<td>80.6</td>
<td>72.9</td>
<td>65.8</td>
<td>49.2</td>
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<tr>
<td>30-50</td>
<td>5.5</td>
<td>99.6</td>
<td>209.9</td>
<td>83.8</td>
<td>182.4</td>
<td>68.8</td>
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<tr>
<td>50-75</td>
<td>2.3</td>
<td>99.9</td>
<td>133.8</td>
<td>90.7</td>
<td>122.5</td>
<td>82.0</td>
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<tr>
<td>75-100</td>
<td>0.8</td>
<td>99.8</td>
<td>64.4</td>
<td>94.0</td>
<td>60.6</td>
<td>88.5</td>
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<tr>
<td>100+</td>
<td>0.7</td>
<td>100.0</td>
<td>109.8</td>
<td>100.0</td>
<td>106.3</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>413.3</td>
<td>1925.8</td>
<td>929.2</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Table 4. Erosion from cropland in the United States in 1977 (USDA, 126)

<table>
<thead>
<tr>
<th>Region</th>
<th>Wind (million tons)</th>
<th>Sheet and rill erosion (million tons)</th>
<th>Excess erosion (1000 acres)</th>
<th>Total erosion (million tons/tons/acre)</th>
<th>Percent of total (Crop­land Erosion</th>
<th>Excess erosion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nation</td>
<td>891</td>
<td>1908</td>
<td>93779</td>
<td>2799</td>
<td>6.8</td>
<td>100</td>
</tr>
<tr>
<td>Northeast</td>
<td>n.e. a</td>
<td>82.9</td>
<td>4204</td>
<td>82.9</td>
<td>5.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Lake States</td>
<td>n.e.</td>
<td>117.5</td>
<td>5637</td>
<td>117.5</td>
<td>2.7</td>
<td>10.7</td>
</tr>
<tr>
<td>Corn Belt</td>
<td>n.e.</td>
<td>688.3</td>
<td>33209</td>
<td>688.3</td>
<td>7.7</td>
<td>21.8</td>
</tr>
<tr>
<td>Iowa</td>
<td>n.e.</td>
<td>261.3</td>
<td>11979</td>
<td>261.3</td>
<td>9.9</td>
<td>6.4</td>
</tr>
<tr>
<td>Northern Plains</td>
<td>212.3</td>
<td>322.4</td>
<td>13954</td>
<td>534.7</td>
<td>5.6</td>
<td>22.9</td>
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<tr>
<td>Appalachia</td>
<td>n.e.</td>
<td>186.3</td>
<td>8121</td>
<td>186.3</td>
<td>9.0</td>
<td>5.0</td>
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<tr>
<td>Southeast</td>
<td>n.e.</td>
<td>111.0</td>
<td>6927</td>
<td>111.0</td>
<td>6.3</td>
<td>4.2</td>
</tr>
<tr>
<td>Delta</td>
<td>n.e.</td>
<td>154.9</td>
<td>9007</td>
<td>154.9</td>
<td>7.3</td>
<td>5.1</td>
</tr>
<tr>
<td>Southern Plains</td>
<td>488.8</td>
<td>141.4</td>
<td>7999</td>
<td>630.2</td>
<td>15.0</td>
<td>10.2</td>
</tr>
<tr>
<td>Mountain</td>
<td>190.3</td>
<td>70.8</td>
<td>2847</td>
<td>261.1</td>
<td>6.2</td>
<td>10.2</td>
</tr>
<tr>
<td>Pacific</td>
<td>n.e.</td>
<td>31.9</td>
<td>1534</td>
<td>31.9</td>
<td>1.4</td>
<td>5.6</td>
</tr>
</tbody>
</table>

^n.e. - not estimated.
One is led to believe that 6.5 billion tons of soil disappear annually—2.8 billion of it from cropland. This impression is reinforced in some of the conservation literature (Sampson, Ill; McLaughlin, 88; Barlow, 8). Actually, the USLE only predicts erosion along the length of a slope to a point of deposition. The amount that eventually leaves a field varies widely. Most of the sheet and rill soil erosion remains in the same field just further down the slope. Wind erosion has comparable effects (Cook, 37; Robinson, 110). While 40% of all sediment is attributed to cropland, the amount of soil movement as calculated by the USLE which actually leaves the farm depends on the watershed, soil type and land topography and may be less than 1% or as high as 55% of the estimated gross soil "loss" (Larson et al., 77; Robinson, 110).

**Trend**

The trend in soil erosion over time is usually assumed to be upward so that there is more erosion now than ever before (Sampson, Ill; Pimental et al., 103). However, recent studies have called this assumption into question. Mayer (84) compared erosion studies from 1934 and 1977 and found that in 1934 erosion was slight on 47% of the cropland, moderate on 38% and severe on 15%. The comparable numbers in 1977 were 77%, 13%, and 10%. He concluded that soil resources improved greatly over the last 50 years. Schultz (113) argues that increases in yields and relocation of crop production activities have reduced erosion associated with most row crops. He also suggests that increases in exports
need not increase soil erosion. Even USDA soil science technicians have been surprised to discover soil loss rates substantially below anticipated levels (Cook, 35). The prevailing wisdom seems to be founded more on opinions than facts. The lack of intertemporal studies has hindered comparisons over time. However, the 1982 NRI will provide data in the near future which can be compared to that of 1977 to assess trend over this period.

**Productivity Effects**

Soil erosion (and formation) affect soil productivity. Erosion reduces productivity by inducing loss of nutrients, organic matter, water retention capacity, and rooting zone depth (Congress of the U.S., 34; Williams et al., 140). It is possible for erosion to have positive productivity effects to the extent that deposition enriches the receiving soil. If subsoils are more productive than topsoils, then further positive productivity impacts occur (Crosson, 38). While soil formation usually has positive effects, such is not always the case (Hall et al., 59). The magnitude of these productivity effects is not yet known, though a number of studies have found a range of local effects. Williams et al. (140) cite studies showing that grain yields in the eastern U.S. declined 30-40% when the A horizon was eroded away; grain yields in Wisconsin and Minnesota were 25-35% less on severely eroded soils. Wheat yields in the Northwest were reduced 60% on desurfaced plots. Some of these same studies suggested that productivity could be restored if sufficient water, mulch and fertilizer were applied.
(Williams et al., 140). The problem with much of this research is that it is dated. Also, most research was conducted at low crop production levels which cannot be extrapolated to current high levels. Additionally, the studies indicate erosion impacts on productivity where erosion is drastic; i.e., little or no top soil is left. Impacts are likely not the same for normal erosive processes where reduction in soil quality is gradual.

A recent effort at USDA to predict effects of erosion on yields assumed a 1% growth rate in yields due to technological change and continued erosion at 1977 levels (Swader, 123). The estimated effects of erosion on yields for several crops in several areas at the end of a fifty year period are shown in Table 5. Overall, yields would be 8% less than they would otherwise have been.

Attempts to relate soil characteristics to yields then show how yields change as erosion alters characteristics have also been undertaken (Larson et al., 77; Pierce et al., 101). The effect of 1977 erosion rates on yields over the next 50 to 100 years was examined for a number of major land resource areas (MLRAs). The areas studied included western Iowa, the Iowa-Missouri border and southeastern Minnesota. With technology, management and factors other than erosion assumed constant, yield losses ranged from 3 to 7% overall. Productivity losses on the steeper slopes were as high as 25%.

Significant model refinements remain to be made and uncertainty requires the accuracy of the estimates derived to be accepted with some reservation. Nevertheless, these efforts coupled with those of USDA's
Table 5. Expected changes in yields of selected crops in selected areas if 1977 erosion rates continue for the next 50 years (Swader, 123)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Producing area</th>
<th>Soil group</th>
<th>1977 soil loss rate (tons/acre)</th>
<th>50 year cumulative loss (inches)</th>
<th>Present yield in 2030 (bu/acre)</th>
<th>Maximum yield in 2030 if present erosion continues in 2030 (bu/acre)</th>
<th>Percentage of maximum yield in 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>Pennsylvania and New York</td>
<td>1</td>
<td>2.5</td>
<td>0.8</td>
<td>101</td>
<td>152</td>
<td>152</td>
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<tr>
<td></td>
<td></td>
<td>2</td>
<td>5.5</td>
<td>1.8</td>
<td>81</td>
<td>121</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>8.1</td>
<td>2.7</td>
<td>74</td>
<td>111</td>
<td>107</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>9.2</td>
<td>3.1</td>
<td>66</td>
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<td>5</td>
<td>13.6</td>
<td>4.5</td>
<td>67</td>
<td>101</td>
<td>94</td>
</tr>
<tr>
<td>Corn</td>
<td>Illinois and Ohio</td>
<td>1</td>
<td>3.9</td>
<td>1.3</td>
<td>105</td>
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<td>42.4</td>
<td>14.1</td>
<td>61</td>
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<td>137</td>
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<td></td>
<td></td>
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<td>5.1</td>
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<td>10.5</td>
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<td>3.2</td>
<td>1.0</td>
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<td>51</td>
<td>51</td>
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<td></td>
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<td>18.0</td>
<td>6.0</td>
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<td>35</td>
<td>21</td>
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<td></td>
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<td>17</td>
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<td>5.8</td>
<td>12</td>
<td>18</td>
<td>16</td>
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</table>
erosion-productivity committee will hopefully lead to a greater understanding of the problems and provide answers useful in improving conservation policy.

Despite the absence of solid information, USDA has attempted to determine how much erosion could be allowed without affecting productivity (see McCormack et al., 86, for a history of such efforts). The tolerance level or T value is defined as the maximum rate of annual soil erosion which permits a high level of productivity to be maintained economically and indefinitely (USDA, 126). Although such a rate could be expected to vary by soil, it is usually considered to be five tons per acre per year. Estimates must be considered crude approximations since little research exists to support them (Congress of the U.S., 34; Williams et al., 140). Early research, though sketchy, suggested that the top layer of soil (the A horizon) formed at 5 tons per acre per year and that gully erosion began at this rate. Both assertions are doubtful in light of present knowledge (Hall et al., 59). The A horizon might be maintained indefinitely but since it forms in the remaining soil (a replacement process), the soil can become thinner even at T value loss rates. On such soils, the maintenance of a favorable rooting zone would be more important than maintenance of the A horizon. If maintenance of a favorable rooting zone is the goal, then many deep soils can tolerate much larger losses than 5 tons per acre per year (Logan, 82). Soil erosion rates alone are obviously not good indicators of damage to soil productivity (Larson et al., 77).

Although it is usually accepted that regeneration is less than
T-values and that T-values are less than current erosion rates of many lands (Logan, 82), only erosion in excess of T is considered excessive. Whether this will reduce long-term productivity is not obvious due to aspects of soil quality and technological change. However, one might ask why erosion control practices are used on lands eroding at less than T values if long-term productivity is not being impaired (Cook, 37).

Using the concept of T-values as benchmarks, Tables 3 and 4 show that excess erosion tends to be concentrated with 3% of soils accounting for nearly 60% of the excess erosion (USDA, 126). The Corn Belt, Southeast, and Delta regions are the areas with the greatest concentrated erosion problems.

Erosion produces offsite as well as onsite productivity effects in the form of increased drainage maintenance and water purification costs, reduced capacities of reservoirs and waterways, damages caused by sediment to bridges, ships, treatment plants, pumps, etc.; and impacts on fish, wildlife and recreational demands. Estimates of the magnitude of such costs are not easily derived. Linking costs to agricultural land is even more tenuous. Pimental et al. (103) cite the following estimates of total sediment related costs: $250 million for dredging rivers and harbors; $50 million in value of lost reservoir capacity; $200 million for other sediment related damages. Crosson and Brubaker (41) calculated such costs to be equivalent to approximately $1 billion in 1980 dollars.

A recent study in the state of Michigan found that elimination of most of the sediment from waterways in that state would not generate large cost savings from dredging and water treatment--$40,000 annual
Further research in this area is warranted but whatever the results, they must be compared with the cost of the alternatives, i.e. soil erosion control. It may well be that some offsite costs can be borne more easily than the costs of preventing erosion in the first place.

Soil Conservation

Soil conservation is invariably viewed as a good—more is preferred to less—even though exactly what it is does not appear to be a subject of wide agreement. A relatively simple definition used above equated conservation to investment in the soil resource. An alternative, equally simple definition would define soil conservation as the slowing or halting of erosion. Any practice reducing the inherent erodibility of a soil in its natural state could be considered conserving. Alternatively, one might view erodibility under current cropping and management practices as the basis for comparison (USLE). Conservation occurs when the use of alternative systems (as noted by changes in the C and P factors of the USLE) result in less gross erosion. The basis for comparison determines what is conserving and what is not.

Ciriacy-Wantrup (26) defined conservation as the redistribution of use in the direction of the future. With respect to soil, this would imply that any practice which led to a greater amount of soil being available in future periods would be conserving. A comparison of at least two usage patterns is necessary although nonuse is not considered an option.

Heady (67) proposed a definition that is more restrictive than
those above. Conservation is defined as the prevention of future productivity losses on a unit of soil given fixed labor and capital inputs. Here, the effect of soil characteristics on productivity must remain unaltered. Erosion can occur as long as the productivity (present or future) of the soil is not affected (given other inputs). If use changes productivity, then conservation practices must restore it. Thus, terraces, crop rotations, minimum tillage, strip cropping and other farming practices which build or keep soil in place are conserving. This definition does not require comparisons among use rates but information about soil productivity and its interactions with cropping, cultivation and management systems.

A fourth definition is implied by Brubaker and Castle (19). Since the productive capacity is important, modification in the form of the capacity may not be as important as maintenance of it. Conservation occurs as technology offsets land losses and overall productivity is unimpaired. Conservation thus might mean the using of one resource for another. Technological change leads to the substitution of labor and capital for land. Less land area is farmed more intensively by using more labor and capital. The focus on productive capacity implies that policies which are demand decreasing or which enhance productive capacity abroad can be soil conserving. There is of course a limit to the amount of soil one would wish to lose due to uncertainty.

Depending on the definition used and/or the basis of comparison involved, a particular practice or technique may or may not be soil conserving. The environmentalist might view the natural state as
optimal and the basis for comparison. Rates of soil loss induced by man would have to be smaller than the sum of natural loss and gross soil formation rates. At the other extreme, anything which maintains productivity could be viewed as soil conserving. Investments in human capital, technology, seed research, production abroad and a number of other factors would be conserving.

The most often-used definition of soil conservation, and the one which will be used in this study, refers to the soil saved by a reduction in present erosion levels. If erosion exceeds T-values, then any practice reducing erosion involves soil conservation. If used as a basis for policy, these definitions still allow for a wide range of alternative investments and/or practices. Although soil conservation and erosion control are not quite synonymous, they are used interchangeably below.
CHAPTER III. ECONOMIC EFFICIENCY AND SOCIAL CHOICE

The role of government in society has probably never been clear cut. A brief perusal of American history reveals a number of conflicts based on differing ideas as to proper use of governmental powers. The first immigrants arrived because a government was perceived to be overly involved in religious affairs. The Revolution occurred when the onus of government became too excessive. The Civil War was fought by factions having differing views as to what constituted legitimate government duties. Today, a myriad of government programs and efforts that began as responses to Depression era problems have come under fire. The political problem for both the administration and the Congress is to determine what level of government intervention is acceptable.

The major justification of government programs is described in the preamble of the constitution wherein society takes collective action in order to "establish justice, insure domestic tranquility, and promote the general welfare" among other things. Recent attempts to circumscribe government powers rely on arguments that excessive use of such action is leading to erosion of freedom (Friedman and Friedman, 54) or that past programs failed to increase the social welfare. It is argued that government has slowed growth, decreased productivity, and stifled progress (Gilder, 56).

What should government do? The question is not easily answered although economists have tried. The criteria, strengths, and weaknesses of the economic approach to social choice are briefly outlined in this chapter. The concepts discussed are applied to soil conservation in an
Economics and the Social Optima

Welfare economics evaluates the desirability of alternative social states. The differing institutions and resource allocation patterns arising from various states cause differences in economic choices. Whether a change from one state to another is desirable or not depends on perceptions of welfare changes. If everyone can be made better off or if anyone can be made better off without anyone being made worse off, a change is desirable. This is the definition of pareto optimality—the efficiency criterion of welfare economics.

Pareto optimality can apply to production, to consumption and to the economy as a whole. Each of these three levels of efficiency is briefly discussed below in the context of a two factor \((X_1, X_2)\), two good \((Y_1, Y_2)\), two consumer world.

Production efficiency

Production is pareto optimal when an increase in the output of one product requires a decrease in the output of the other. Let the production processes be represented by the functions \(Y_1 = F_1(X_{11}, X_{21})\), \(Y_2 = F_2(X_{12}, X_{22})\). With fixed input quantities, the problem is formulated as maximization of

\[
L = F_1(X_{11}, X_{21}) + \lambda_1(Y_2^s - F_2(X_{12}, X_{22})) + \lambda_2(Y_1^s - X_{11} - X_{12}) \\
+ \lambda_3(Y_2^s - X_{21} - X_{22}) \\
\]

(1)
First order conditions imply that

\[ \frac{\partial F_1}{\partial X_{11}} \frac{\partial X_{12}}{\partial F_1} = \frac{\partial F_2}{\partial X_{21}} \frac{\partial X_{22}}{\partial F_2} . \]  

(2)

That is, the marginal rate of substitution of \( X_1 \) for \( X_2 \) must be equal in the production of both goods. In addition, production must occur along the production possibility frontier \( (Y_2^o - F_2(X_{12}, X_{22}) = 0) \). All points on the frontier are efficient in the sense that increasing production of one good requires decreasing production of the other. No reallocation of inputs will yield a greater quantity of one without decreasing the other. Points inside the frontier are not efficient since the same amount of \( X_1 \) and \( X_2 \) could produce more of either \( Y_1 \) or \( Y_2 \) or both.

**Consumption efficiency**

Pareto optimality in consumption requires that each consumer's utility be at a maximum given every other individual's utility. A reallocation would result in at least one person being made worse off. Let \( U_1(Y_{11}, Y_{21}), U_2(Y_{12}, Y_{22}) \) be the utility functions of the two individuals where \( Y_1^o = Y_{11} + Y_{12} \), and \( Y_2^o = Y_{21} + Y_{22} \). Maximize the utility of individual 1 subject to a constraint on the utility of individual 2 \( U_2 = U_2^o \),

\[ L = U_1(Y_{11}, Y_{21}) + \lambda_1 (U_2^o - U_2(Y_{12}, Y_{22})) + \lambda_2 (Y_1^o - Y_{11} - Y_{21}) \]

\[ + \lambda_3 (Y_2^o - Y_{21} - Y_{22}) \]  

(3)
Evaluation of first order conditions yields

\[ \frac{\partial U_1}{\partial Y_{11}} \cdot \frac{\partial Y_{12}}{\partial U_1} = \frac{\partial U_2}{\partial Y_{22}} \cdot \frac{\partial Y_{12}}{\partial U_2} \]  

(4)

The marginal rate of substitution of \( Y_1 \) for \( Y_2 \) must be the same for all consumers and consumption must be along the utility possibility frontier \( (U_2^o - U_2(Y_{12}, Y_{22}) = 0) \).

**Economy wide efficiency**

For an entire economy, an infinite number of utility possibility frontiers exist. The envelope of all such curves is termed the grand utility possibility curve. Along this frontier, it is impossible to modify production and/or consumption to increase \( U_1 \) without decreasing \( U_2 \). The locus of overall pareto optimal points can be defined by maximizing \( U_1(Y_{11}, Y_{21}) \) subject to \( U_2(Y_{12}, Y_{22}), Y_1 = Y_{11} + Y_{12}, Y_2 = Y_{21}, Y_{22}, \) and \( Y_1 = \gamma(Y_2, X_1, X_2) \). The last three equations describe the production possibilities curve and may be combined in implicit form to yield

\[ h(Y_1, Y_2) = 0 \]  

(5)

The lagrangian function is

\[ L = U_1(Y_{11}, Y_{21}) + \lambda_1 (U_2^o - U_2(Y_{12}, Y_{22})) + \lambda_2 h(Y_1, Y_2) \]  

(6)

The first order conditions are manipulated to yield

\[ \frac{\partial U_1}{\partial Y_{11}} = \frac{\partial U_2}{\partial Y_{12}} = \frac{\partial h}{\partial Y_1} = -\frac{\partial Y_2}{\partial Y_1} \]  

(7)
That is, the marginal rate of substitution in consumption between two goods is the same across all consumers and equal to the marginal rate of transformation between the two goods. These results can be generalized to n goods, m consumers and s inputs (Henderson and Quandt, 68).

There are still an infinite number of pareto efficient points with no way to distinguish which is best. Indeed, even points inside the grand utility possibility frontier may be superior to an "efficient" point. Pareto efficient production and consumption are necessary but not sufficient for welfare maximization. The determination of the optimal point requires a social welfare function. Given such a function, the problem is solved and running back through the analysis determines the allocation of \( X_1 \) and \( X_2 \) in production and \( Y_1 \) and \( Y_2 \) in consumption.

**Problems with the Social Optima**

Several problems exist in applying the above methodology. The social welfare function determines whose values or ethics count and is not scientifically derivable. The maximization of social welfare \( W \) where \( W = W(U_1, U_2, \ldots, U_m) \) requires that

\[
\frac{\partial W}{\partial U_1} dU_1 + \frac{\partial W}{\partial U_2} dU_2 + \cdots + \frac{\partial W}{\partial U_m} dU_m = 0 .
\]

(8)

Determination of the most efficient policy requires knowledge of the individual weights \( \frac{\partial W}{\partial U_1} \), and these are unknown because of the infeasibility of interpersonal comparisons.

If it is assumed that each individual counts and that pareto optimality in production and consumption is a desirable state of
affairs, then the grand utility possibility frontier is the measuring stick. In this case, only knowledge regarding the direction of change \((dU)\) is forthcoming. This is not particularly helpful since, as shown above, an infinite number of efficient points exist and nothing can be said about changes which make one individual better off and another worse off. Policy evaluation is foreclosed since this describes the usual situation.

The failure of the above approach led to development of compensation tests (Henderson and Quandt, 68). The Kaldor criterion judges a policy or state of affairs to be more efficient than another if a move to it allows gainers to more than adequately compensate losers. The Hicks criterion holds that efficiency is increased if, after a change, losers cannot compensate gainers. The Scitovsky criterion requires both of the above conditions to be met when prices change. The difficulty of compensation tests is that only potential rather than actual welfare is considered since such payments need not be made. Additionally, transactions costs associated with compensation may actually lead to a reduction in welfare.

The economic approach to determination of the proper role of government suggests that governments should promote pareto efficiency thereby maximizing social welfare (Atkinson and Stiglitz, 6). However, in application, pareto optimality is too normative for some, fails to consider other objectives, and does not adequately model the reality of the political process (Bromley, 17; Schmid, 112; Steiner, 119; Wildavsky, 139).
It is argued that marginal rates of substitution and transformation are determined by prices and these as well as the ability to compensate depends on the initial distribution of property rights (Mishan, 92; Randall, 104; Schmid, 112). Because of this, efficiency and distributional questions cannot be separated (Bromley, 17; VanKooten, 136). The end result is that for the economy as a whole, no fully adequate efficiency criterion for comparison of alternative policies or states of nature exists in the absence of value judgments (Ladd, 75).

Efficiency in Policy Analysis

In conducting policy analysis, economists have shied away from the use of social optima due to the problems mentioned above (Castle et al., 24; Andrews, 2). Despite economists' inability to specify a socially optimal policy, welfare economics provides a framework for analyzing the impacts of policies and policy changes. With respect to soil conservation policy, economic analysis could focus on the level of investment in conservation. The effects of a change in the amount being spent could be examined to see who gains and who loses. However, this is not the level of analysis undertaken here. Government-sponsored soil conservation efforts will undoubtedly be continued. It is also unlikely that the level of government involvement in soil management will change by any order of magnitude. Political decisions are made incrementally so funding levels will likely remain near present levels (Crosson, 38).

An alternative application of welfare economics would be to focus on the effects of changes in policy or programs given the level of investment. In the absence of distributional considerations, efficiency
would require achievement of the largest possible returns from the investment. If this occurs, then production efficiency results whether or not overall pareto optimality exists. This is the concept of efficiency that will be used in the remainder of the study. It is the basis of the analysis of soil conservation policy.

Economists have advocated production efficiency while realizing that it is not all that matters (Schultze, 114; Haveman, 62). Efficiency criteria are used for a number of reasons. First, basing decisions on a systematic, reasoned approach is likely to produce consequences superior to those that would arise from following purely stochastic behavior (Krutilla, 74). Production efficiency assures that a minimum of resources is expended in reaching a goal. Second, the results of such analyses can be viewed as informative rather than prescriptive in nature (Randall, 105). The efficiency view is thus presented as one of several viewpoints to be considered. Third, political decisions may be efficient politically but need not be from any other point of view (Haveman, 60; Robbins, 109). Economic efficiency is at least as legitimate as other advocacy roles and should be considered. Explicitly defined value judgments can then be combined with objective analyses to form a "political economy". Fourth, economics can trace the relationship between policies and the results of policies (Stigler, 120). Past mistakes can be examined and future ones may be avoided. Fifth, it is often possible to show what is wrong even if what is right or best is not determined (Baumol, 11). While distributional and other issues are not clear cut, the efficiency aspects of alternative programs provide
Government, Market Failure, and the Soil Resource

The equality of the marginal rates of substitution and the marginal rates of transformation necessary for pareto optimality is guaranteed in purely competitive markets since prices are the same for all producers and consumers (Henderson and Quandt, 68). In such cases, private markets maximize social welfare and governments need not interfere (Davis and Kamien, 45). The absence of markets or the occurrence of joint production, externalities, public goods, monopoly or other deviations render pareto efficient production and/or consumption uncertain. Market failure distorts prices so that economic efficiency is no longer guaranteed.

When market failure leads to pareto or production inefficiency, there is usually pressure to overcome it through collective action. However, market failure is usually a matter of degree and the transactions costs impeding markets can be reduced through a variety of social institutions of which government is only one (Arrow, 4). Social norms of behavior can be established in ways other than governmental forms (Young, 143) so that evidence of market failure is not a sufficient condition for government intervention. Indeed, it has been shown that governmental efforts to remedy perceived market failures have been the most important sources of inefficiency in resource allocation (Stiglitz, 121).

Three broad levels of market failure are alleged to exist with respect to soil use: (1) markets undervalue the soil resource;
markets function but individual decision makers fail to act optimally; (3) externalities are present. Each of these is considered in more detail.

Undervaluation

Conservationists sometimes argue that markets do not adequately reflect the value of soil with the result that too little conservation occurs (Sampson, ill). Economic theory suggests that the capitalized value of a farmer's land is equal to the sum of the discounted net returns to the land into the indefinite future (Melichar, 89). To the extent that this occurs, even those who plan to hold land only for a short period of time must be sensitive to the long run effects of their actions. If the farmer is unable to capture all of the returns to land (externalities exist) or if he discounts at a higher rate than society, then land will be undervalued by that individual from a social viewpoint. It could then be argued that land markets are myopic and fail to adequately perceive the future.

The myopia argument might proceed along several different lines. First, the market determined value of the soil may be inaccurate because of incorrect assessments of future food and fiber demands, rates of technological change, and/or land supplies by market participants (Crosson and Brubaker, 41). If the market underestimates demand or overestimates supply the soil will be undervalued. Second, a lack of knowledge regarding the linkage between erosion and productivity over time may also yield undervaluation. Farmers may fail to consider the
diminution in future production caused by present erosion. Third, it is possible that the market gives less weight to productivity maintenance as a hedge against uncertainty than does society (Crosson and Miranowski, 42). Society must plan as if it is immortal and must protect the interests of future generations (Brubaker, 18). This difference in responsibility to the future between the market and society may result in a market-determined soil value which is less than society's valuation.

It obviously is important to know whether or to what extent under-valuation occurs. While the evidence has yet to be carefully studied, it would seem unlikely that policy makers or others outside the land market have superior information to that of market participants. This would cast considerable doubt on the first and second reasons above as a basis for governmental intervention. The third reason is the basis for Ciriacy-Wantrup's safe minimum standard of conservation (25). Other economists have also seen it as the most important argument supporting undervaluation (Crosson and Brubaker, 41; Crosson and Miranowski, 42).

**Decision maker failure**

It may be the case that markets accurately reflect societal values but participants are unable to provide the optimal level of conservation. Irrationality, competitive pressures, capital constraints, and institutional arrangements may lead to a kind of market failure (Crosson and Brubaker, 41).

Land is the farmer's most important asset and substantial incentives exist to acquire and act on information that will maintain or protect
his investment in this asset. It seems highly unlikely that farmers will act irrationally in making land use decisions.

A farmer may find that competitive pressures or capital constraints keep him from making optimal investments in the soil resource. While a financial squeeze may force a farmer to ignore long run effects of present actions, if the market is functioning, such a situation can only be temporary. He will likely compare the effects of erosive practices with those arising from conservation practices and choose the course of action which yields the highest capitalized value. Government assistance can shorten the duration of such temporary situations.

Institutional arrangements may also yield temporary deviations from the optimal investment strategies. It is suggested that soil investment decisions will be different for corporate farms than owner operators, and that these will differ from those made by tenants (Lee, 78). McConnell (85) has shown that if markets function, corporations and owner operators that face the same prices and use the same inputs will make identical conservation decisions. It is true that tenants will make different land use decisions since they do not bear long run erosion costs. However, owners who rent may require tenants to adopt conservation practices or may invest in such practices themselves. Owners with substantial interests outside agriculture may respond somewhat slower than owner operators but if markets are functioning, they may be expected to take action. In fact, Lee and Stewart found higher conservation tillage adoption rates among part owner and tenant farmers than among full owner operators.
Fiscal policy may also introduce distortions preventing optimal use of conservation practices. Tax policy may lead to increased erosion if it encourages short term investment in agriculture by outside investors. If the primary motive for holding land is for its preferred tax status, the incentive to maintain soil productivity may be absent.

Additionally, certain landowners may deduct the cost of some soil conservation practices as an operating expense. Landowners must "materially participate" and deductions are limited to 25% of gross farm income in any one year. The effects of the deduction depend on the size of the expenditure, the amount of farm and nonfarm income, and the size of the deduction. While the deduction has been linked to an increased likelihood of practice adoption, other variables were much more important and tax policy was found to play only a minor role in the adoption decision (Davenport et al., 44). Nevertheless, Boron suggests that removal of the restriction on nonoperator landlords would increase conservation practice usage.

Externalities

Market failure may also result from externalities in the form of offsite pollution damages. Farmers cannot be expected to provide the optimal level of conservation if many of the benefits accrue to society at large. The major impact of soil erosion has been found to be offsite in nature (McConnell, 85; Dechant, 46). Although important, this argument has received little attention in present policy formation (Crosson and Miranowski, 42).
In summary, the three main justifications for government investment in soil conservation on market failure grounds would seem to be (1) maintenance of soil productivity as insurance against an uncertain future; (2) overcoming obstacles that prevent farmers from making optimal investments on their own; and (3) internalization of externalities borne at present by society.

As mentioned above, evidence of market failure and/or inefficient private behavior, while necessary, is not sufficient to justify governmental attention (Rausser, 108). Farm leaders, conservationists, and politicians are seemingly aware of the weakness of the arguments for government investment in conservation (Dechant, 46; Giltmeier, 57). Therefore, in the absence of such 'sufficient' evidence, government investment has been justified on ethical grounds. A conservation ethic is promoted. The ethic, based on principles of stewardship, advocates leaving the land unchanged. Since farmers are not adhering to such an ethic on their own, government efforts are seen as being necessary to assist some and force others to believe and act accordingly (Sampson, 111).

Despite economic and ethical arguments for government investment in the soil resource, conservation measures to date appear to be undertaken as a means to achieve other goals (Strohbehn, 122). These other goals have included support of farm prices, raising farm income, increasing agricultural productivity and reducing input costs. This view may change as further research broadens our understanding of resource adequacy, the nature of technological change, erosion-productivity
linkages, institutional constraints, and the extent of offsite damages (externalities).

Program Review and Evaluation

Soil conservation has been on the national agenda at least since 1929 when $160,000 was allocated to establish erosion measurement stations and fund related research. Subsequent legislation authorized data collection activities as well as the development of soil conservation districts to oversee conservation funding. There are now 34 programs administered by the USDA which deal with soil and water conservation (USDA, 127). Although multiple objectives exist, only the soil conservation aspects of the various programs are presented below.

Present programs provide technical assistance to aid farmers in developing a conservation plan. Payments to farmers who use approved conservation practices or reduce the tillage of erosive soils are provided on a cost share basis. Long term agreements to reduce erosion are encouraged and best management practices are promoted through financial and technical assistance. Loans and tax deductions are provided as incentives, research is funded and education is promoted all with the goal of increasing soil conservation. Spending for soil conservation amounted to about $1 billion in 1982 (Leman and Miranowski, 81).

Despite these numerous programs, soil erosion problems remain—23% of the farmland in the U.S. erodes at what is termed an unacceptable rate (USDA, 126). A major shortcoming of the policy-making process has been the failure to perform program evaluations and thereby develop an
analytical basis on which policy decisions could be justified (Leman, 80). The data for such appraisals were not even collected prior to the 1970s. However, as pressures for efficiency in government increased, congressional attention was focused on soil conservation programs by a number of studies. The General Accounting Office found inefficient practices in a number of programs and suggested that evaluations and a number of changes be made (Comptroller General of the U.S., 28-33). The environmental movement also added impetus to such a drive. The National Resource Inventory (NRI) and the Soil and Water Resources Conservation Act of 1977 (RCA) were the results. The NRI collected data necessary for evaluation efforts, while the RCA required the USDA to appraise the condition of soil and water resources, evaluate existing programs, and develop a national soil and water conservation program. The appraisal based on NRI and other data has been completed (USDA, 126, 127) and a program has been proposed (USDA, 128). However, the program evaluation phase has largely been ignored (Leman, 80; Congress of the U.S., 34).

Some program evaluations have arisen as outgrowths of the earlier General Accounting Office studies or as the result of presidential requests. The Soil Conservation Service (SCS) evaluated the Great Plains Conservation Program in 1974 and concluded that more soil could be conserved with no increase in cost by redistributing funds among states. An even greater amount of erosion control could be achieved if conservation practices on farms were modified (USDA, 132). The Resource Conservation and Development Act was reviewed (USDA, 134) and as part of
an ongoing study, the Agricultural Conservation Program (ACP) was evaluated for the 1975-1978 period (USDA, 129). The ACP study found that the amount of soil conservation obtained under the program could be tripled without increasing costs by directing practices to the most erosive soils. Further increases in conservation would occur if the most efficient conservation practices were utilized by individual farmers.

These evaluation results have given rise to the concept of improving governmental efficiency by targeting an increased proportion of USDA conservation program funds to specific areas of the country and to specific practices (USDA, 128). Targeting of assistance as a means of increasing efficiency of conservation efforts has been called the 'wave of the future' (Meyers, 90).

**Targeting proposals**

Criteria for effective targeting have been suggested in a number of studies and program proposals. As administered by the SCS, the portion of Conservation Technical Assistance (CTA) funds targeted is to be allocated to special geographic areas with the most "persistent and critical" erosion problems. Specific considerations for an area to be so designated include (1) the severity (tons/acre) and the extent (number of acres involved) of the erosion problem; (2) expected results; (3) willingness of farmers in the area to participate; and (4) the effect of erosion on agricultural productivity and its linkage to offsite damages (USDA, 131). The first three are briefly discussed in the program outline, although no specific performance measures are
presented. How severe does the erosion problem have to be? What percentage of farmers must be willing to participate? The effect of erosion on productivity is not mentioned further. Since so little is known about the subject, such an approach is understandable; yet productivity maintenance is one of the main justifications given for erosion control in the RCA program document (USDA, 128). The CTA program further provides for local, state and federal cooperation in the targeting of additional funds based on the size and extent of the problem, the type of agriculture involved, the number of farms involved and "significant social and economic" conditions. There is thus ample room for interpretation. Indeed, the criteria are such that the broad geographic areas delineated to date include over 33 million acres for 1981-1982 program benefits, about that many more for 1983, and 80 million acres more in subsequent years. This targeting proposal would eventually allocate CTA funds to over 35% of U.S. cropland. However, the funds involved are miniscule—less than 1% of the SCS budget and less than 2% of conservation technical assistance funds in 1981. The amount is slated to increase by up to 5% of the CTA budget per year until 25% of CTA funds are targeted.

Other suggestions with respect to targeting have called for funds to be targeted to "critically erosive lands", "special areas", and "areas with acute treatment needs" (Ogg et al., 99). These are all later defined to be areas whose soils account for most of the erosion and sedimentation in the country. Taken literally, this would seem to focus conservation efforts on the 8.7% of cropland which accounts for
52% of all erosion or about 36 million acres.

A third proposal focuses efforts where there is an identified physical problem as measured by soil depth and erosion rates (Ogg and Miller, 97). A fourth proposal targets matching grant funds to geographic land areas having critical soil erosion or upstream flooding problems of national significance as determined by the SCS (USDA, 130).

The ACP evaluation suggested targeting according to the potential for erosion reduction and on the most efficient practices (USDA, 129). This approach is said to direct assistance according to the extent and efficiency with which soil erosion problems will be solved. The RCA Program Report suggested targeting to critical areas on the basis of the threat to productivity of the soil. The broadest proposal simply suggests focusing on erosion prone soils (Sampson, 111).

All currently proposed sets of targeting criteria include in some form the idea that severity of erosion is important where severity is measured in tons/acre. The assumption is that the greater the loss, the greater is the problem; i.e., the more serious the productivity loss and the greater the offsite damages. Although further considerations include soil depth, sedimentation, productivity, results expected, willingness of farmers to participate, and the most efficient (least cost) practices, these are largely secondary or noted as limitations of the various studies. Thus, evaluations to date have used primarily a physical efficiency criterion (gross soil loss) whose accuracy and relevance are questionable (Cook, 37; Congress of the U.S., 34; Sampson, 111). This approach assumes all soils are equally productive and yield equal
amounts of offsite damages while denying that some resources are more valuable than others or that some soils may not be worth conserving.

Inadequate information has hindered the assessment of productivity impacts and the valuation of different soil types. The effects of specific practices on productivity and soil loss are unknown as are the offsite damages linkage to erosion and the erosion control production function. If soils vary in value (productivity) or if the amount of offsite damages are not directly related to the amount of erosion, then present evaluation efforts that provide measures of conservation in terms of tons of soil can be misleading. Targeting recommendations based on such evaluations are wasteful to the extent that low valued soils (or those yielding small offsite damages) are conserved while high valued soils (or those associated with large offsite damages) erode away. It seems that economic criteria must be combined with the physical criteria to increase the efficiency of soil conservation efforts. Such economic criteria for improving soil conservation efforts are developed in Chapter IV from a profit maximizing model. Then, in Chapter V, the implications of the criteria are examined by estimating implicit prices of soil conservation.
CHAPTER IV. THE ECONOMIC FRAMEWORK OF CONSERVATION

Although Heady (66, 67), Bunce (20), Hotelling (70), Ciriacy-Wantrup (25) and others presented the economics of soil use prior to the early 1950s, little more was done on the subject until the mid-1970s. Burt (21) suggests that this inactivity resulted as technology diminished the role of soil resources in production. During the 1970s, studies began examining erosion as it affected water quality. The Center for Agricultural and Rural Development at Iowa State University performed a number of such analyses using a national linear programming model (Holding, 69). There and elsewhere, research focused on the optimal form of government policy and the optimal on farm conservation practices (Ogg et al., 98). Recent research has focused on the dynamics of soil use (Burt, 21; Shortle, 117; McConnell, 85). Little, however, has been done from a policy evaluation perspective.

Analytical Problems

Economic analysis of soil resource use is difficult and complex. The allocation of soil among uses and over time is a problem in capital theory made even more difficult by the multi-dimensional nature of the resource. While the quantity of soil used is obviously important, so is its quality. However, quality can be measured in a number of ways—soil depth, percent organic matter, tilth, rooting zone, slope, etc. These factors vary by site so that it is difficult to consider soil as a homogeneous resource and proceed in the usual fashion. Furthermore, soil is only one of many inputs in the production of agricultural
commodities. Water, sunlight, air, climate, labor, and capital (machinery, knowledge, nutrients) are also necessary. There are tradeoffs between soil and other inputs and between other inputs and soil characteristics. Such tradeoffs not only occur within a specific planning period but extend over time.

Technical change poses additional problems. Changes in technology are important determinants of substitution; yet the future direction and rate of such changes are unknown. Capturing the dynamic aspect of soil use is compounded by inadequate information on such changes as well as on the rates of formation and/or depletion of soil and soil characteristics.

Externalities also complicate the analysis. Joint outputs from the production process include sediment, nutrients, and other chemicals encompassed in soil erosion, as well as desired agricultural commodities. Costs arising from such incidental outputs are usually incurred by others in the form of offsite externalities. Furthermore, some inputs such as soil characteristics are not individually priced. The lack of a complete set of input and output prices limits economic analysis.

The multiple objectives associated with soil use also give rise to modeling difficulties. The farmer wishes to earn a comfortable living and is often assumed to maximize profits. He may also have objectives of good stewardship, minimizing risk or staying in business all of which may cause actions to diverge from those derived from profit maximization. Society has long had low cost food and fiber as an objective. More recently, the desire for clean air, clean water, and open spaces as well
as the social goals of family farms and a guarantee of adequate cropland for future generations have become important considerations in soil use decisions. Economic analysis usually assumes maximization of an objective function and when multiple objectives exist, weights for each objective must be applied if the analyst is to provide quantifiable results.

A Static Economic Model

A simple production model that ignores many of the above issues yet provides useful insight into soil use and conservation decisions is presented below. Simplifying assumptions are later dropped to examine the effects of time on the optimal resource allocation criteria. Although the simple model is well-known in economics, it is reviewed as a basis for developing a more realistic model and to highlight its implications for soil conservation which might otherwise be overlooked.

Consider an implicit agricultural production function of the form

$$ F(Y_1 \ldots Y_n, X_1 \ldots X_m) = 0 \quad (9) $$

Let the $Y_i$'s be outputs and the $X_j$'s be inputs. Outputs include corn, soybeans, other agricultural commodities and soil erosion. Inputs include labor, capital (tillage equipment, conservation practices, etc.), water, and soil (organic matter content, soil depth, etc.). The function is assumed to possess continuous first and second order partial derivatives and thus allows for joint products (Mittelhammer et al., 94). Let profits be given as
\[ \pi = \sum_{i=1}^{n} P_i Y_i - \sum_{j=1}^{m} R_j X_j \] (10)

where \( P_i \) and \( R_j \) are prices of the \( i \)th output and \( j \)th input. The producer maximizes profits subject to a production function constraint so that his objectives may be expressed as the maximization of \( L \) where

\[ L = \sum_{i=1}^{n} P_i Y_i - \sum_{j=1}^{m} R_j X_j + F(Y_1, ..., Y_n, X_1, ..., X_m) \] (11)

The partial derivatives (first order conditions) are:

\[ \frac{\partial L}{\partial Y_i} = P_i + \frac{\partial F}{\partial Y_i} = 0 \quad i = 1, ..., n \] (12)

\[ \frac{\partial L}{\partial X_j} = -R_j + \frac{\partial F}{\partial X_j} = 0 \quad j = 1, ..., m \] (13)

\[ \frac{\partial L}{\partial \lambda} = F(Y_1, ..., Y_n, X_1, ..., X_m) \] (14)

These conditions summarize the accepted rules for optimal production. Condition 12 can be interpreted as follows: \( P_i \) is the marginal value of output and \( \lambda \frac{\partial F}{\partial Y_i} \) is the change in the value of total production that results from the last unit of \( Y_i \) produced. To produce \( Y_i \), production of other outputs had to be adjusted. The term \( \lambda \frac{\partial F}{\partial Y_i} \) can thus be viewed as a marginal opportunity cost of producing \( Y_i \). Condition 12 requires that marginal benefits equal marginal costs.

In Condition 13, \( R_j \) is the marginal resource cost and \( \lambda \frac{\partial F}{\partial X_j} \) is the marginal value of the last unit of resource used. Again, marginal costs are equated to marginal benefits. Condition 14 insures the technological conditions of production are not violated.

Using 12, letting \( i = 1 \), \( k \) and moving the second term to the right
yields (by the implicit function rule)

\[
\frac{P_1}{P_k} = \frac{\partial F/\partial Y_1}{\partial F/\partial Y_k} = -\frac{Y_k}{Y_1}. \tag{15}
\]

The marginal rate of transformation between products equals the price ratio. Let the two products under consideration be soil erosion from two types of soil. The relative value of the soils should equal the rate at which the soils can be substituted for each other. Soils might be viewed as substitutes to the extent that productivity rates and erosivity vary. If soil 1 is twice as productive as soil k, then from a productivity point of view, one ton of soil erosion from soil 1 can be substituted for two tons of soil erosion from k. According to equation 15, soil 1 should therefore be twice as valuable as soil k, other things being equal. One ton of soil of type 1 saved need not equal a ton of type k, although this is the assumption that underlies most evaluations and targeting proposals to date.

Consider equation 13 where \( j = 1, m \). With appropriate manipulation and by invoking the implicit function rule,

\[
\frac{R_1}{R_m} = \frac{\partial F/\partial X_1}{\partial F/\partial X_m} = -\frac{X_m}{X_1}. \tag{16}
\]

The marginal rate of substitution between inputs is equal to the price ratio. Optimal allocation would find conservation practice one substituting for practice two at the rate \( R_1/R_2 \).

For any output \( i \) and input \( j \) from equations 12 and 13,

\[
\frac{R_1}{P_i} = \frac{\partial F/\partial Y_1}{\partial F/\partial Y_i} = \frac{Y_1}{Y_i} \quad \text{or} \quad R_j = P_i \frac{\partial Y_i}{\partial X_j} \quad \text{or} \quad \frac{P_i}{R_j} \frac{\partial Y_i}{\partial X_j} = 1 \tag{17}
\]
The value of the marginal product (MVP) of any input should be equal to its price. In other words, the ratio of the value of the marginal product to input price should equal one for efficient resource utilization. Government investment in conservation occurs because of perceived nonoptimal resource allocation. That is, $\text{MVP}_{ij}/R_j \neq 1$ where $\text{MVP}_{ij}$ is the marginal value product of input $j$ in the production of output $i$. Given limited resources, it may not be possible to extend resource use to the point that a dollar's worth of input yields a dollar's worth of output. In such a case, the best that can be done is to use resources in producing products with the greatest return on investment. This occurs when the following conditions hold:

$$\frac{\text{MVP}_{11}}{R_1} = \frac{\text{MVP}_{12}}{R_2} = \frac{\text{MVP}_{21}}{R_1} = \cdots = \frac{\text{MVP}_{ij}}{R_j} \quad \text{for } i = 1 \ldots n \quad j = 1 \ldots m \quad (18)$$

These conditions provide the economic rationale for targeting. Funds should be targeted to those inputs (soils and practices, for example) with the largest marginal value product to price ratio. This will result in the greatest return on investment and efficient resource allocation. Other things being equal, conservation efforts should be focused on those areas where the economic damage due to erosion is the greatest. This need not be where soil erosion is occurring most rapidly.

Externalities and other forms of market failure can be incorporated into the above framework through the cost or benefit side. Consider Figure 2 where the farmer's optimal level of erosion is represented by $0_F$. The $MC_F$ curve traces out the marginal costs of reducing erosion while the $MB_F$ curve represents the marginal benefits of reducing erosion.
Figure 2. A farmer's view of the optimal level of soil erosion

Figure 3. The optimal level of soil erosion as perceived by society
While the present analysis is static, in an intertemporal sense, the curves could be viewed as marginals of the sum of the discounted cost and benefit streams. Note that low levels of erosion are associated with small benefits and large costs of erosion control while the opposite is true at high levels of erosion (USDA, 129). Figure 2 depicts marginal costs and benefits from the farmer's point of view.

In Figure 3, society's values are shown along with the farmer's. Society incurs additional cost from erosion so that at any level of erosion, the marginal benefits from reducing erosion are greater than those perceived by the farmer (MBg). Societal marginal benefits might include all those perceived by the farmer plus the value of reduced off-site effects and any additional benefits due to market failure. The resulting social optimum, Os, yields less erosion than the farmer finds optimal.

In order to reduce erosion to Os, U.S. policy makers have chosen to subsidize conservation practices which effectively shifts the curve MCp in Figure 3 to the left. An optimal subsidy (s) would result in MCps. In terms of the model presented above, the marginal cost to the farmer is no longer Rj but (1-s)Rj. Optimal resource allocation requires

$$ R_j = \frac{\partial Y_i}{\partial X_j} $$

(19)

$$ (1-s)R_j = \frac{\partial Y_i}{\partial X_j} $$

(20)

where $P_i^S$, $P_i^F$ are the values of $Y_i$ (soil erosion or soil conservation)
from society's and the farmer's respective points of view. From equations 19 and 20,

\[ sR_j = (p^S_i - p^F_i) \frac{\partial y_i}{\partial x_j} \text{ or } \]

\[ \frac{\partial sR_i}{\partial y_i} = p^S_i - p^F_i \text{ .} \]  

The difference in soil values between a farmer and society may reflect not only offsite effects but the value of differences between market and social responsibility to the future. To the extent that other sources of failure (mentioned previously) exist, they are also accounted for in this term. Thus, \( p^S_i - p^F_i \) is a measure of the extent or cost of market failure.

A major problem of the above formulation is the failure to include time. Decisions in the present period will affect future options and this is especially true for the soil resource. A decision to erode a soil in one period obviously affects the amount and quality of soil available in future periods. A modification to allow consideration of such effects is developed in the next section.

An Intertemporal Economic Model

Consider a farmer who desires to optimize a production plan over \( T \) periods. The implicit production function is

\[ f(Y_{11}, \ldots, Y_{NT}, X_{11}, \ldots, X_{MT}, K_1, \ldots, K_T) = 0 \]  

where \( Y_{it} \) \((i = 1 \ldots N, t = 1 \ldots T)\) is the amount of product \( i \) produced in period \( t; X_{jt} \) \((j = 1 \ldots M, t = 1 \ldots T)\) is the amount of input \( j \) used
in period \( t \); and \( K_t \) \((t = 1 \ldots T)\) is the soil stock in period \( t \). The soil stock changes over time according to

\[
K_{t+1} = K_t + g_t(Y_{11} \ldots Y_{N_t}, X_{11} \ldots X_{M_t}, K_1 \ldots K_t).
\]

That is, this period's soil stock is equal to last period's plus net soil formation

\[
g_t(Y_{11} \ldots Y_{N_t}, X_{11} \ldots X_{M_t}, K_1 \ldots K_t).
\]

Net soil formation includes both soil generation and soil erosion and is affected by previous outputs, inputs and levels of soil stock. The measurement problems associated with the dynamics of soil formation and soil erosion were discussed previously. Making this equation operational might be done in several ways. Burt (21) used the percentage of organic matter as a measure of the stock while Shortle (117) used soil depth. For present purposes, the conceptual approach is sufficient.

The maximization of profits in any period is defined as

\[
\text{Max } \pi_t = \sum_{i=1}^{N} P_{it}Y_{it} - \sum_{j=1}^{M} R_{jt}X_{jt}.
\]

However, the objective over time is to maximize the discounted value of the profit stream. Let the discount factor be

\[
\beta^t = 1/(1+r)^t.
\]

Then, where \( t = 1 \ldots T \),

\[
\pi = \sum_{t=1}^{T} \beta^t \pi_t = \sum_{t=1}^{T} \beta^t \left( \sum_{i=1}^{N} P_{it}Y_{it} - \sum_{j=1}^{M} R_{jt}X_{jt} \right).
\]
There will also be a 'terminal value' at the end of the planning period. Assume that all fixed inputs except land are fully depreciated and have no value at the end of period $T$. The value of land is assumed to be the sum of the discounted net returns into the indefinite future and will depend on soil stock in period $T+1$. Let this value be denoted as $V(K_{T+1})$.

The optimization problem is formulated as

$$\text{Max} \left[ \sum_{t=1}^{T} \beta^t \left( \sum_{i=1}^{N_i} p_{it} y_{it} - \sum_{j=1}^{M} r_{jt} x_{jt} \right) + \beta^{T+1} V(K_{T+1}) \right]$$

subject to a production function constraint,

$$f(Y_{11} \ldots Y_{N_t}, X_{11} \ldots X_{M_t}, K_1 \ldots K_t) = 0 \quad \text{(30)}$$

the soil stock equation of motion,

$$K_{t+1} - K_t - g(Y_{11} \ldots Y_{N_t}, X_{11} \ldots X_{M_t}, K_1 \ldots K_t) = 0 \quad \text{(31)}$$

and nonnegativity constraints on inputs, outputs, and soil stocks,

$$X_{jt}, Y_{it}, K_t \geq 0 \quad \text{for all } i,j,t \quad \text{(32)}$$

The corresponding lagrangian expression (33) includes both discounted ($\lambda$) and undiscounted multipliers ($\delta_{t+1}$). The latter are discounted by the factors $\beta^{t+1}$.

$$L = \sum_{t=1}^{T} \left( \sum_{i=1}^{N} p_{it} y_{it} - \sum_{j=1}^{M} r_{jt} x_{jt} \right) \beta^t + \beta^{T+1} V(K_{T+1}) + \lambda f(Y_{11} \ldots Y_{N_t}, X_{11} \ldots X_{M_t}, K_1 \ldots K_t)$$

$$- \sum_{t=1}^{T} \delta_{t+1} \beta^{t+1} (K_{t+1} - K_t) - g(Y_{11} \ldots Y_{N_t}, X_{11} \ldots X_{M_t}, K_1 \ldots K_t) \quad \text{(33)}$$
The Kuhn-Tucker conditions listed below characterize the solution to the problem if one exists. In any period 1\(\leq t \leq T\) and for \(j = 1 \ldots M, i = 1 \ldots N\), these are:

\[
\frac{\partial L}{\partial Y_{it}} = \beta^t p_{it} + \lambda \frac{\partial f}{\partial Y_{it}} + \delta^t_{t+1} \beta^{t+1} \frac{\partial q_{it}}{\partial Y_{it}} = 0; \quad Y_{it} \geq 0 \tag{34}
\]

\[
\frac{\partial L}{\partial X_{jt}} = -\beta^t K_{jt} + \lambda \frac{\partial f}{\partial X_{jt}} + \delta^t_{t+1} \beta^{t+1} \frac{\partial q_{jt}}{\partial X_{jt}} = 0; \quad X_{jt} \geq 0 \tag{35}
\]

\[
\frac{\partial L}{\partial K_t} = \lambda \frac{\partial f}{\partial K_t} + \delta^t_{t+1} \beta^{t+1} (1 + \frac{\partial q_{t}}{\partial K_t}) - \beta^t \delta^t_t = 0; \quad K_t \geq 0 \tag{36}
\]

\[
\frac{\partial L}{\partial V} = f(Y_{11} \ldots Y_{NT}, X_{11} \ldots X_{MT}, K_1 \ldots K_T) = 0 \tag{38}
\]

\[
\frac{\partial L}{\partial \delta^t_{t+1}} = K_{t+1} - K_t - \delta^t_t (Y_{11} \ldots Y_{NT}, X_{11} \ldots X_{MT}, K_1 \ldots K_T) = 0 \tag{39}
\]

In order to derive values for the multipliers \(\delta_t, t = 1 \ldots T\), \(K_t\) must be positive in all periods. It seems safe to assume that soil stocks will remain at positive levels. Also, in equations 34 and 35, if \(Y_{it}\) and \(X_{jt}\) are to be nonnegative, these conditions require equality to zero and this will be used in what follows.

Condition 36 is a recursive relation in \(\delta_t\). From 36,

\[
\delta_t = \lambda \beta^{-t} \frac{\partial f}{\partial K_t} + \delta^t_{t+1} \beta (1 + \frac{\partial q_{t}}{\partial K_t})
\]

\[
= \lambda \beta^{-t} \frac{\partial f}{\partial K_t} + [\lambda \beta (-t+1) \frac{\partial f}{\partial K_{t+1}} + \delta^t_{t+2} \beta (1 + \frac{\partial q_{t+1}}{\partial K_{t+1}})] (1 + \frac{\partial q_t}{\partial K_t}) \beta \tag{40}
\]
Completing the iteration and using equation 37 yields

\[
\delta_t = \lambda \beta^{-t} \frac{\partial f}{\partial k_t} + \left[ (\lambda \beta^{-k} \frac{\partial f}{\partial k_k}) \beta(1 + \frac{\partial g_k}{\partial k_k}) \right] + \beta(1 + \frac{\partial g_k}{\partial k_k}) + \beta(1 + \frac{\partial g_k}{\partial k_k}) . \tag{41}
\]

The interpretation of equation 41 is more easily made after additional manipulation. From equation 24,

\[
\frac{\partial K_{t+1}}{\partial K_t} = 1 + \beta \frac{\partial g_t}{\partial K_t} . \tag{42}
\]

Successive application of the chain rule for implicit functions gives

\[
\frac{\partial K_k}{\partial K_t} = \beta(1 + \frac{\partial g_k}{\partial k_k}) \tag{43}
\]

and substituting 43 into 41 yields

\[
\delta_t = \sum_{k=t}^{T} \beta^{-k} \lambda \frac{\partial f}{\partial k_k} \frac{\partial K_k}{\partial K_t} + \beta^{T-t} \frac{\partial g_k}{\partial k_k} \frac{\partial K_T}{\partial K_t} . \tag{44}
\]

The second term on the right is the value in period t of changes in the terminal value function resulting from the use of soil stock in t. The first term is the value in t of changes in the value of production over all periods of time resulting from soil stock changes in t. Thus, \( \delta_t \) is the marginal effect of soil stock use in t on production in all periods and on the terminal value. It is the present value of the sacrifices being imposed on the future and may be termed the user cost of soil. It is possible for the user cost to be negative if diminished stocks increase the value of production more than they decrease the terminal value.

Conditions 34 and 35 are similar in interpretation to equations 12 and 13 of the simple model. Moving price to one side and dividing by \( \beta^t \).
in 34 yields
\[ p_{it} = -\rho^t \frac{\partial f}{\partial y_{it}} - \delta^t \beta \frac{\partial g}{\partial y_{it}} \]  \hspace{1cm} (45)

The first term on the right is the marginal opportunity cost in production while the second term is the marginal cost associated with stock changes arising from production of \( Y_{it} \). Here, marginal benefits are equated to marginal costs and the latter includes future as well as present costs.

Similar manipulation of 35 yields
\[ r_{jt} = \lambda \rho^t \frac{\partial f}{\partial x_{jt}} + \delta^t \beta \frac{\partial g}{\partial x_{jt}} \]  \hspace{1cm} (46)

The price of an input is equated to its value in current production plus its marginal value in all future periods as reflected by the change in stocks it delivers times the user cost. Again, the result is similar to the static model only now, the effect on the future must also be considered.

Form the ratio of 26 and 27. After rearranging terms,
\[ -\frac{r_{jt}}{p_{it}} - \delta^t \beta \frac{\partial g}{\partial x_{jt}} = \beta^{\tau-t} \frac{\partial f}{\partial x_{jt}} = -\beta^{\tau-t} \frac{\partial y_{it}}{\partial x_{jt}} \]  \hspace{1cm} (47)

for all \( t, \tau = 1 \ldots T, i = 1 \ldots N, j = 1 \ldots M \). Further manipulation of 37 yields
\[ r_{jt} = \beta^{\tau-t} p_{it} \frac{\partial y_{1t}}{\partial x_{jt}} + \delta^t \beta \frac{\partial g}{\partial x_{jt}} + \beta^{\tau-t+1} \delta \frac{\partial g}{\partial y_{it}} \frac{\partial y_{1t}}{\partial x_{jt}} \]  \hspace{1cm} (48)
and, where $t = \tau$

$$R_{jt} = P_{it} \frac{\partial Y_{it}}{\partial X_{jt}} \quad j = 1 \ldots M \quad i = 1 \ldots N \quad (49)$$

Equation 49 is comparable to 17 of the static model and has an analogous interpretation. An input should be used up to the point where marginal cost just equals marginal benefit. Since both inputs and outputs are in the same period, it is a comparative static condition. Where input and output effects are in different periods of time, equation 48 requires the marginal value product be adjusted to a common time period (discounted to $t$) and the change in user costs between time periods must be added.

Since soil stocks are included in the intertemporal production function, the impact on production from a change in stocks arising from changes in input $j$ and output $i$ is considered. Relationships similar to 15 and 16 can be derived in the same way as 48 and 49 and allow calculation of the marginal rates of transformation and marginal rates of substitution.

Equation 48 also imposes a flow condition in terms of the optimum rate of use of the stock. The rate of natural resource use at any point in time should be such that the marginal value of output is equal to the marginal opportunity cost of resources used plus a marginal user cost.

Condition 36 imposes an additional stock condition. Moving $\beta^t_{\delta_t}$ to the right and multiplying by $\beta^{-(t+1)}$ in 36 gives
\[ \lambda \beta^{-1}(t+1) \frac{\partial f}{\partial K_t} + \delta_{t+1} + \delta_{t+1} \frac{\partial g}{\partial K_t} = \delta_t (1+r) \]  
(50)

rearranging terms

\[ r \delta_t = \lambda (1+r)^{t+1} \frac{\partial f}{\partial K_t} + (\delta_{t+1} - \delta_t) + \delta_{t+1} \frac{\partial g}{\partial K_t}. \]  
(51)

That is, the stock of the resource at any point in time should be such that the opportunity cost of holding the stock \((r \delta_t)\) just equals the marginal value of the stock in production plus the appreciation of the stock plus the value of the stock in producing soil. From equation 51, it is possible to derive the behavior of the user cost over time:

\[ \delta_{t+1} - \delta_t = r \delta_t - \delta_{t+1} \frac{\partial g}{\partial K_t} - \lambda (1+r)^{t+1} \frac{\partial f}{\partial K_t}. \]  
(52)

Letting time periods become very short,

\[ \frac{d \delta t}{dt} = r \delta_t - \delta_{t+1} \frac{\partial g}{\partial K_t} - \lambda (1+r)^{t+1} \frac{\partial f}{\partial K_t}. \]  
(53)

and the rate of change is thus

\[ \frac{d \delta t}{\delta t} = r - \frac{\delta_{t+1} \frac{\partial g}{\partial K_t}}{\delta_t} - \lambda (1+r)^{(t+1)} \frac{\partial f}{\partial K_t}. \]  
(54)

The rate of change in user cost equals the rate of interest less a factor which reflects the effect of the stock on soil formation \((\frac{\partial g}{\partial K_t})\) and on production \((\frac{\partial f}{\partial K_t})\). Let the rate of formation be invariant to the stock \((\frac{\partial g}{\partial K_t} = 0)\). If \(\frac{\partial f}{\partial K_t} > 0\), then user cost grows at a rate less than \(r\). In this case, a change in the soil stock has a positive effect on productivity so that either a dividend accrues to holding soil in place.
\((dK_t > 0)\) or a premium is attached to soil stock depletion \((dK_t < 0)\).

When \(\frac{\partial f}{\partial K_t} < 0\), user cost grows more rapidly than \(r\) so that a penalty is attached to soil stock changes.

Assume \(\frac{\partial f}{\partial K_t} = 0\) and \(\frac{\delta^t \delta^{t+1}}{\delta_t} > 0\). Then, if \(\frac{\partial g}{\partial K_t} > 0\), the rate of growth in user cost is less than the rate of interest. A dividend on investments in soil maintenance \((dK_t > 0)\) or erosive activities \((dK_t < 0)\) results since future costs are reduced from what they would have been otherwise. When \(\frac{\partial g}{\partial K_t} < 0\), the user cost grows at a rate greater than \(r\). The difference is due to the increased costs imposed on the future as changes in the soil stock decrease soil formation.

When both productivity and soil formation are unaffected by stock changes, then user cost grows at the rate of interest. This is the classical result derived by Hotelling (70).

Interest usually focuses on price rather than user cost. In the formulation of the model, erosion was assumed to be an output even though it could be viewed as an input. The reason for this can now be clarified. If farmers optimally allocate resources so that condition 47 is satisfied, the marginal product \(\frac{\partial Y_{it}}{\partial X_{jt}}\) takes into account present decision's effects on the future. Assuming accurate measures of \(\frac{\partial Y_{it}}{\partial X_{jt}}\) and \(R_{jt}\) are available, the implicit value of \(Y_{it}\) (that is \(P_{it}\)) can be found. Where \(R_{jt}\) is the price of a conservation practice and \(Y_{it}\) is erosion in \(t\), then \(P_{it}\) is the value of a ton of soil erosion.

The rate of change in soil value under optimal management can be calculated. Using the discrete time approach used thus far, condition 45 implies that optimal prices in \(t\) and \(t+1\) will be
Subtracting 55 from 56 gives

\[ \beta^{t+1} P_{it+1} - \beta^t P_{it} = -\lambda \frac{\partial f}{\partial Y_{it+1}} - \frac{\partial f}{\partial Y_{it}} - \delta_{t+2} \beta^{t+2} \frac{\partial g}{\partial Y_{it+2}} \]

\[ + \delta_{t+1} \beta^{t+1} \frac{\partial g}{\partial Y_{it}}. \]  

Let \( \frac{\partial g}{\partial Y_{it+1}} = -1 \) where \( Y \) is the rate of erosion (no soil formation occurs under this assumption). Multiplying by \( \beta^{-(t+1)} \) yields

\[ P_{it+1} - P_{it} \beta^{-1} = -\lambda \beta^{-(t+1)} \frac{\partial f}{\partial Y_{it+1}} - \frac{\partial f}{\partial Y_{it}} + (\delta_{t+2} - \delta_{t+1}) \]

substituting \( 1/(1+r) \) for \( \beta \) and rearranging terms gives

\[ P_{it+1} - P_{it} = r P_{it} - \lambda (1+r) \beta^{t+1} \frac{\partial f}{\partial Y_{it+1}} - \frac{\partial f}{\partial Y_{it}} + (\delta_{t+2} - \delta_{t+1}) + r \delta_{t+2}. \]

Let time periods become very short so that

\[ \frac{dP_i}{dt} = r - \lambda \left[ \frac{\partial f}{\partial Y_{it+1}} - \frac{\partial f}{\partial Y_{it}} \right] - \frac{1}{P_i} (\delta_{t+2} - \delta_{t+1}) - \frac{r}{P_i} \delta_{t+2}. \]  

The rate of change in price equals the rate of interest less a factor which reflects the changes in marginal production costs and user costs. There is nothing in equation 60 that would keep price from falling.
The application of equation 60 is not likely to be possible in a short time period. Substantial variations in product prices will likely cause wide gyrations from the optimal time path in specific years. Analysis in the next section focuses on valuing soil but does not consider the time paths of such values.
CHAPTER V. CONSERVATION BENEFITS: DATA, ANALYSIS, AND RESULTS

As noted in the review of the literature, there is little information on how erosion affects soil productivity. An important research need is to measure and evaluate the damage due to erosion or, conversely, the benefits of soil conservation. The application of the economic model outlined above meets this need by allowing the calculation of implicit soil prices. Such prices can be viewed as measures of erosion-induced productivity losses or as measures of the benefits of conservation. This chapter contains a discussion of the data used in the analysis and the method of estimation. Additionally, the hypothesis that soil productivity varies by region and that such differences are reflected in soil values is tested. The implications for targeting are also discussed.

Data

The Agricultural Stabilization and Conservation Service (ASCS) operates offices in some 2700 counties. In 1977, the ASCS began in evaluation of the Agricultural Conservation Program (ACP) using a random sample of 171 counties. Data were collected from each of these counties for the years 1975-1977 and the early part of 1978. ASCS offices in the selected counties supplied information on each soil and water conservation practice for which cost sharing was provided. The data used here include only those observations dealing with sheet and nill erosion. These observations include information on the type of practice, the priority given the practice in the county, the size and type of farm using the
practice, whether long term and/or pooling agreements were involved, the total cost of installing the practice, the percentage subsidized, and the number of acres treated or served by the practice. Additionally, data necessary to use the Universal Soil Loss Equation were obtained for each practice and estimates of soil loss before and after practice application were calculated.

Similar information on these counties was obtained in 1981 and 1982. However, after the initial (1975-1978) data were obtained and evaluated, ACP objectives were modified in an effort to increase program effectiveness. Legislative changes further altered the program so that data from the different time periods likely constitute two different sets of information.

The present research focuses on Iowa and the Corn Belt. Since the original sample was evidently drawn on a national rather than a stratified (regional) basis, sample points may not be accurate indicators of the desired populations. Additionally, information on every participant in a selected group of counties is available, but there is no information on nonparticipants. Statistics would be descriptive of those receiving conservation practice payments but may not apply to other farmers in the county.

Implicit Soil Prices

Factors affecting price

It is hypothesized that the implicit price of a ton of soil (the cost of a ton of soil erosion on the benefits of conserving a ton of
soil) varies with soil productivity and therefore by soil classification, susceptibility to erosion, climate, type of farming, land use and other factors impinging on soil productivity. These factors are all used in delineating major land resource areas (MLRAs) (Austin, 7). Therefore, the price of a ton of soil is expected to vary across MLRAs. In Iowa, a ton of soil conserved might be valued quite highly in MLRA 109 where soil is thin, less highly in 108 where soils are moderately deep, and valued least in 107 where top soils are very deep. Similarly for the Corn Belt, soils in MLRAs 115 and 116 are not very productive from an agricultural point of view, and so conservation of such soils may not be very highly valued. Knowledge of where the most valuable soils are in terms of conservation benefits has obvious targeting implications. A brief description of the MLRAs in Iowa and the Corn Belt is provided in Table 6.

Besides regional differences, implicit soil prices and conservation practices used are likely to be interrelated. Particular practices are likely to be well-suited to particular land uses and/or soil patterns. The practices considered herein are predominant in the Corn Belt and include permanent vegetative cover establishment, terracing, and conservation tillage. Permanent vegetative cover practices are not likely to be used on highly valued soils since the value of soil productivity with these practices is usually lessened from that of normal agricultural practices. Terracing and conservation tillage are more likely to be associated with soils of greater value.

A third factor hypothesized to be related to the value of
Table 6. Characteristics of major land resource areas (Austin, 7)

<table>
<thead>
<tr>
<th>Region</th>
<th>Location</th>
<th>Characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>107</td>
<td>Western Iowa</td>
<td>60% cropland, deep loess hills, steep rolling hills, highly erosive.</td>
</tr>
<tr>
<td>108</td>
<td>Central Iowa, Illinois</td>
<td>75% cropland, deep loess soils, level to rolling hills.</td>
</tr>
<tr>
<td>109</td>
<td>Southern Iowa, Northern Missouri</td>
<td>50% cropland, thin loess soils, rolling to undulating slopes</td>
</tr>
<tr>
<td>111</td>
<td>Indiana, Ohio</td>
<td>80% cropland, gently sloping, some hills.</td>
</tr>
<tr>
<td>113</td>
<td>Northeast Missouri, Western Illinois</td>
<td>60% cropland, level to gently sloping, clay pan.</td>
</tr>
<tr>
<td>114</td>
<td>Southern Illinois, Indiana</td>
<td>50% cropland, moderately thick loess soils, level to gently sloping ridge-tops, narrow flood plains with steep valley sides.</td>
</tr>
<tr>
<td>115</td>
<td>Central Mississippi Valley (IL, IND, MO)</td>
<td>40% cropland, rolling ridge tops, steep ridge and valley sides are wooded</td>
</tr>
<tr>
<td>116</td>
<td>Southern Missouri (Ozarks)</td>
<td>20% cropland, deeply weathered limestone, some steep slopes</td>
</tr>
<tr>
<td>122</td>
<td>Southern Indiana</td>
<td>40% cropland, level with some areas of steep hills and narrow valleys</td>
</tr>
</tbody>
</table>
conserving a ton of soil is the prepractice erosion rate. The value of a ton of soil subject to extreme erosion might be expected to be less than that of a ton which differs only in its susceptibility to erosion. The less erosive soil is likely to remain in production longer or require less investment to maintain it in production so it will be more valuable. Since a farmer will have to take costly conservation measures to maintain erosion soil in place, the value of an erosive soil is likely to be less than that of soil not requiring treatment, other things equal.

It may also be argued that soils that are being allowed to erode rapidly are those that are less favorable to crop production and other agricultural uses. The inherent productivity is less, so farmers are willing to pay a premium for better, less erosive land. The premium is paid only if the productivity benefits so obtained are greater than those which could be obtained by fertilizing, installing conservation practices, or otherwise treating the poorer land at a similar cost.

Estimated prices

The implicit prices are calculated based on the assumption that farmers are economically rational. If a farmer had perfect knowledge of the impact of erosion on future productivity and followed optimal decision rules (equations 48 and 49), then marginal costs (including user costs) would be equated to marginal benefits (including changes in an intertemporal production function) in making all production decisions. Although perfect knowledge does not exist, farmers have an incentive,
as discussed earlier, to make decisions incorporating long-run considerations. It is likely, therefore, that some measure of user cost is included in the assessment of marginal cost and that intertemporal effects are included in evaluating marginal benefits. The decision rules represented by equations 48 and 49 are, therefore, approximated. That is, marginal costs in the present period plus user costs are equated to discounted marginal benefits. In terms of conservation practices, a practice is used up to the point where marginal cost just equals marginal benefits.

In equation 49, let \( Y_i \) be soil erosion and \( \frac{\partial Y_i}{\partial X_j} \) be the amount of soil saved by the last unit of a conservation practice, \( X_j \). \( P_i \) is the implicit price of a ton of soil erosion, and \( -P_i \) is the implicit price of a ton of soil conserved using practice \( X_j \). This is the amount a farmer is willing to pay for a ton of soil conserved. It is assumed that farmers consider the long-run impacts of present practices so that the dynamic criteria are approximated and implicit prices reflect those derived in a dynamic framework.

In order to derive estimates of \( \frac{\partial Y_i}{\partial X_j} \) and \( R_j \), several assumptions are necessary. First, it is assumed that the onsite marginal products of a practice are constant for all acres in a given observation. Since the number of acres served by the various practices in a particular observation is generally less than 30, it seems likely that the area treated is relatively homogeneous. If this is the case, the amount of erosion reduction per acre will be the same for each acre treated.

Second, it is assumed that marginal costs are constant. The farmer
does not affect input prices. Since land is homogeneous, marginal costs will be equal to average costs.

Third, the onsite marginal products of the various practices are similar when prepractice erosion rates are the same.

The data were grouped by prepractice erosion rates and the average reduction in erosion as well as average practice costs per acre at each rate were calculated. Following the approach used in the ACP evaluation, the costs were annualized by amortizing the total costs of installing the practice at 8% over a three-year period for permanent vegetative cover and over a 20-year period for terracing. Although the actual data are averages ($/acre and tons/acre), they may be considered marginal given the assumptions above. They are also marginal in the sense that in going from one level of erosion to another, an additional C tons/acre of soil are saved at a cost of R per ton.

Using the cost and erosion reduction figures as measures of marginal costs and marginal products, the implicit price of a ton of soil conserved was calculated for the 22 different prepractice erosion rates defined in Table 7 by MLRA. Equations 19 and 20 were employed to obtain implicit prices at both farmer and societal levels. For example, the average erosion reduction on soils with prepractice erosion rates between 10 and 11 (group 10) in MLRA 108 was 6.27. The average cost per ton of erosion reduction to the farmer was $39.29. The implicit farm value of a ton of soil saved is therefore $6.27 \left( F = \frac{R}{M} = \frac{39.29}{6.27} \right).

The 1981-1982 period implicit prices for MLRAs in Iowa are shown in Table 8. Calculated prices from the 1975-1978 period exhibit
Table 7. Prepractice erosion rate groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Prepractice erosion rate</th>
<th>Group</th>
<th>Prepractice erosion rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>$z &lt; 1$</td>
<td>11</td>
<td>$11 \leq z &lt; 12$</td>
</tr>
<tr>
<td>1</td>
<td>$1 \leq z &lt; 2$</td>
<td>12</td>
<td>$12 \leq z &lt; 13$</td>
</tr>
<tr>
<td>2</td>
<td>$2 \leq z &lt; 3$</td>
<td>13</td>
<td>$13 \leq z &lt; 14$</td>
</tr>
<tr>
<td>3</td>
<td>$3 \leq z &lt; 4$</td>
<td>14</td>
<td>$14 \leq z &lt; 15$</td>
</tr>
<tr>
<td>4</td>
<td>$4 \leq z &lt; 5$</td>
<td>15</td>
<td>$15 \leq z &lt; 20$</td>
</tr>
<tr>
<td>5</td>
<td>$5 \leq z &lt; 6$</td>
<td>20</td>
<td>$20 \leq z &lt; 25$</td>
</tr>
<tr>
<td>6</td>
<td>$6 \leq z &lt; 7$</td>
<td>25</td>
<td>$25 \leq z &lt; 30$</td>
</tr>
<tr>
<td>7</td>
<td>$7 \leq z &lt; 8$</td>
<td>30</td>
<td>$30 \leq z &lt; 50$</td>
</tr>
<tr>
<td>8</td>
<td>$8 \leq z &lt; 9$</td>
<td>50</td>
<td>$50 \leq z &lt; 75$</td>
</tr>
<tr>
<td>9</td>
<td>$9 \leq z &lt; 10$</td>
<td>75</td>
<td>$75 \leq z &lt; 100$</td>
</tr>
<tr>
<td>10</td>
<td>$10 \leq z &lt; 11$</td>
<td>99</td>
<td>$z \geq 100$</td>
</tr>
</tbody>
</table>
Table 8. Implicit price of a ton of soil by Major Land Resource Area and prepractice erosion rate in Iowa—1981-1982

<table>
<thead>
<tr>
<th>Prepractice erosion rate</th>
<th>Farmer value</th>
<th>Societal value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MLRA 107</td>
<td>MLRA 108</td>
</tr>
<tr>
<td></td>
<td>MLRA 107</td>
<td>MLRA 108</td>
</tr>
<tr>
<td>0</td>
<td>42.30</td>
<td>7.18</td>
</tr>
<tr>
<td>1</td>
<td>2.91</td>
<td>3.84</td>
</tr>
<tr>
<td>2</td>
<td>1.24</td>
<td>4.14</td>
</tr>
<tr>
<td>3</td>
<td>2.08</td>
<td>2.14</td>
</tr>
<tr>
<td>4</td>
<td>1.28</td>
<td>1.70</td>
</tr>
<tr>
<td>5</td>
<td>3.30</td>
<td>2.03</td>
</tr>
<tr>
<td>6</td>
<td>3.21</td>
<td>2.20</td>
</tr>
<tr>
<td>7</td>
<td>1.17</td>
<td>.77</td>
</tr>
<tr>
<td>8</td>
<td>.69</td>
<td>6.27</td>
</tr>
<tr>
<td>9</td>
<td>.98</td>
<td>2.08</td>
</tr>
<tr>
<td>10</td>
<td>.78</td>
<td>.85</td>
</tr>
<tr>
<td>11</td>
<td>.80</td>
<td>1.09</td>
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<tr>
<td>12</td>
<td>.55</td>
<td>.49</td>
</tr>
<tr>
<td>13</td>
<td>.60</td>
<td>.53</td>
</tr>
<tr>
<td>14</td>
<td>.37</td>
<td>.59</td>
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<tr>
<td>15</td>
<td>.98</td>
<td>.35</td>
</tr>
<tr>
<td>16</td>
<td>.44</td>
<td>.26</td>
</tr>
<tr>
<td>17</td>
<td>.26</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>.35</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>.10</td>
<td>.06</td>
</tr>
</tbody>
</table>
similar patterns but are not presented.

The results imply that at present cost share rates, society values a ton of soil conserved roughly twice as highly as individual farmers. That is, total offsite costs including valuation of all forms of market failure are approximately equal to onsite costs. The private valuation of land based on its productivity will lead to the same relative values across areas as does a societal valuation—at least in the region under consideration.

In general, the value of a ton of soil saved declines as the pre-practice erosion rate increases. This is in agreement with the hypothesized effect. It was also hypothesized that conserved soils would be more highly valued in 109 than in 107. Examination of the results in Table 8 indicates that this is the case on the less erosive soils.

The use of conservation practices is quite region specific. In Iowa, 89% of the terracing occurs in MLRA 107, while 77% of conservation tillage practices are in 108 and 75% of all permanent vegetative cover observations are in 109.

Preliminary estimates of implicit soil prices indicate that the marginal ton of soil saved by terracing in a particular region is more highly valued than that saved by conservation tillage and these are both more valuable than a ton of soil saved using permanent vegetative cover. While differences across regions were expected, the extent of the intraregional variances was surprising. If the value of the soil saved by terracing in regions 108 and 109 is greater than that saved by
permanent vegetative cover, why is terracing not the predominant practice form?

One possible explanation is that soils are not homogeneous, even within the groupings considered. An additional unit of terracing within a prepractice erosion rate group in 108 or 109 may have higher marginal costs or lower marginal benefits. In 107, marginal costs and/or benefits may be relatively constant over a wide range. The fact that conservation tillage and permanent vegetative cover are not used equally within 108 and 109 may be based on a similar argument. Thus, within an erosion rate group, soils may vary in value so that practices differing in cost can be used on the 'same' soil. Aggregating on prepractice erosion rates across all practices puts soils of differing values together and biases comparisons across regions.

A second form of bias arises from the nature of the costs used in estimating the implicit soil prices. These costs are exclusive of technical assistance and indirect costs arising from practice usage. It is possible that conservation tillage and permanent vegetative cover practices reduce normal operating costs (labor and fuel savings in particular) while terracing increases them (Miranowski et al., 91). Thus, the soil prices estimated when only installation costs are used may be over- or underestimates of actual soil values. Assuming that indirect costs or cost savings associated with a given conservation practice are similar across all major land resource areas, a more accurate model of soil values would compare the implicit prices associated with terracing in one region to those associated with terracing in another and
similarly for other practices. This would also account for lack of homogeneity in erosion rate groupings.

One other change can be made to improve the model. The numbers used to represent marginal costs and marginal products are aggregated averages over all observations at a particular erosion rate. In order to determine whether or not soil price differences are significant, the original unaggregated data need to be used. A model of soil values can then be estimated econometrically using such data. Hypothesis testing procedures can be performed to assess the accuracy of the model. Statistical tests are explained in the next section.

The data in Table 8 indicate that soil values are negatively related to the prepractice erosion rate. This may be because less erosive soils are more productive, or stay in production longer, or because such soils are less costly to farm. A plot of the data in Table 8 in price-prepractice erosion rate space suggests the functional form of an equation expressing price as a function of the erosion rate. Let ER be a variable representing the prepractice erosion rate and let P be the estimated value of a ton of soil conserved calculated for each observation. For small values of ER, ER^{-1} approximates P. As ER increases, ER^{-2} adds explanatory power. It is hypothesized that land use, soil, climate and other differences can be accounted for using major land resource areas. Therefore, regional dummy variables are included in the model. Dummy variables are also used to allow practices to vary with soil values. The differential effect of the erosion rate variables across regions is included by using an interaction term between these
variables and the regional dummies.

The resulting equation for Iowa is:

\[ P = \alpha + \beta_1 ER^{-1} + \beta_2 ER^{-1/2} + \beta_3 D107 + \beta_4 D107ER^{-1} + \beta_5 D107ER^{-1/2} \]
\[ + \beta_6 D107P4 + \beta_7 D108 + \beta_9 D108ER^{-1} + \beta_10 D108ER^{-1/2} \]
\[ + \beta_{11} D108P4 + \beta_{12} D108P15 \]  \hspace{1cm} (61)

where variables are as defined in Table 9. Since three major land resource areas are represented, the regional dummy for region 109 is excluded to avoid perfect collinearity. Estimated coefficients on the dummy variables measure deviations in value from that in region 109. This approach assumes that the error term has a constant variance across regions and prepractice erosion rates. Although the data are cross sectional, there does not appear to be a good reason to expect heteroscedasticity to be a problem for values arising from different regions. However, the data appear to indicate that prices are more variable on lower erosive than higher erosive soils. The Goldfeld-Quandt test was used to test the null hypothesis that the variance was proportional to \( ER^{-1} \). The hypothesis was rejected. Therefore, it was assumed that the error structure was homoscedastic.

Equation 61 was estimated using the Iowa observations in the 1975-1978 data set, the 1981-1982 data set, and a pooled set. An F-test indicated that there was a significant difference between the restricted and unrestricted sums of squares. Therefore, the hypothesis of a common population was rejected and results from the separate regressions are reported.
Table 9. Definition of variables used in regression analysis

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P$</td>
<td>Estimated value of a ton of soil conserved</td>
</tr>
<tr>
<td>$ER^{-1}$</td>
<td>Inverse of the prepractice erosion rate</td>
</tr>
<tr>
<td>$ER^{-2}$</td>
<td>Inverse of the square of the prepractice erosion rate</td>
</tr>
<tr>
<td>$P49$</td>
<td>Practice dummy for terracing in region 109 (0,1)</td>
</tr>
<tr>
<td>$P159$</td>
<td>Practice dummy for conservation tillage in region 109 (0,1)</td>
</tr>
<tr>
<td>$Di^a$</td>
<td>Regional dummy; 1 if region $i$, 0 otherwise</td>
</tr>
<tr>
<td>$DiER^{-1}$</td>
<td>Product of $Di$ and $ER^{-1}$</td>
</tr>
<tr>
<td>$DiER^{-2}$</td>
<td>Product of $Di$ and $ER^{-2}$</td>
</tr>
<tr>
<td>$DiP4$</td>
<td>Practice dummy for terracing in region $i$ (0,1)</td>
</tr>
<tr>
<td>$DiP15$</td>
<td>Practice dummy for conservation tillage in region $i$ (0,1)</td>
</tr>
</tbody>
</table>

$a_i = 107, 108, 111, 113, 114, 115, 116, 122$—the major land resource areas in the Corn Belt.
The regression results for Iowa (Table 10) show that a number of variables in the 1975-1978 model are not statistically significant. F-tests indicate that implicit prices in regions 107 and 109 are significantly different. Furthermore, terracing and permanent vegetative cover practices are used on soils of significantly different values. The results of the 1981-1982 estimation are not as clear cut. While no single variable is significant at a level of significance less than .08, significant differences in prices in regions 107 and 109 do exist. The relatively high $R^2$ coupled with the low t-values suggests the presence of multicollinearity. Alternative model specifications all resulted in similar collinearity problems.

Estimated implicit soil prices using the coefficients in Table 10 indicate that for the 1975-1978 period, soils saved using permanent vegetative cover were most highly valued in region 107 and least in region 108. With terracing, soils in 109 had the lowest price. The 1981-1982 results were quite different. Implicit soil prices using permanent vegetative cover were least in 107 and greatest in 109. With terracing, soils were valued most highly in 108 and least in 107. If more accurate (efficient) funding resulted from program changes in the latter period, this regression may be a more accurate indicator of current soil values. While the 1981-1982 data support the hypothesized relationships, the earlier data do not. Given the program changes and the difficulty of interpreting coefficients when multicollinearity exists, it is doubtful whether any useful information sufficient to
Table 10. Results of Iowa Soil Conservation price estimation

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>t-ratio</td>
</tr>
<tr>
<td>Intercept</td>
<td>.14</td>
<td>.48</td>
</tr>
<tr>
<td>ER^{-1}</td>
<td>4.10</td>
<td>3.64</td>
</tr>
<tr>
<td>ER^{-2}</td>
<td>-1.43</td>
<td>-2.47</td>
</tr>
<tr>
<td>D107</td>
<td>-.24</td>
<td>-.34</td>
</tr>
<tr>
<td>D107ER^{-1}</td>
<td>6.89</td>
<td>1.35</td>
</tr>
<tr>
<td>D107ER^{-2}</td>
<td>1.03</td>
<td>.71</td>
</tr>
<tr>
<td>D107P4</td>
<td>3.23</td>
<td>5.03</td>
</tr>
<tr>
<td>D108</td>
<td>-.51</td>
<td>-.37</td>
</tr>
<tr>
<td>D108ER^{-1}</td>
<td>-6.55</td>
<td>-.29</td>
</tr>
<tr>
<td>D108ER^{-2}</td>
<td>38.49</td>
<td>.44</td>
</tr>
<tr>
<td>D108P4</td>
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<td>4.86</td>
</tr>
<tr>
<td>D108P15</td>
<td>1.42</td>
<td>1.50</td>
</tr>
<tr>
<td>D109P4</td>
<td>1.77</td>
<td>1.74</td>
</tr>
<tr>
<td>$R^2$</td>
<td>.26</td>
<td>.68</td>
</tr>
</tbody>
</table>
accept or reject hypothesized relationships arises from this approach. It can be noted, however, that in alternative tests with aggregated data, hypothesized relationships could not be rejected.

**Corn Belt**

The same procedure of estimating implicit prices and testing for significance was carried out using information for the Corn Belt. All observations from the states of Illinois, Indiana, Iowa, Missouri and Ohio, representing the major land resource areas described in Table 6, were used. The differences in the values of a ton of soil conserved across practices are similar to those discussed above. An expanded, modified version of equation 61 which contained variables for the regions in the Corn Belt was estimated using data from the 1975-1978 and 1981-1982 samples. Again, the hypothesis of a common population was rejected so that separate regressions for each period were used. The null hypothesis of homoscedasticity was not rejected. The results are displayed in Table 11.

A number of variables do not appear to be significant. However, F-tests on variable groupings by region indicate that prices are usually significantly different from those in region 109. In the 1975-1978 model, prices in regions 107, 114, 115 and 122 are significantly different at a level of .01 while those in regions 108, 111 and 116 are different at a level of .05. Differences between prices in 109 and 113 are not significant. F-tests on the 1981-1982 model found no statistically significant differences between region 109 prices and those in
Table 11. Results of Corn Belt soil conservation price estimation

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>t-ratio</td>
<td>Coefficient</td>
<td>t-ratio</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>1.10</td>
<td>2.89</td>
<td>1.82</td>
<td>2.97</td>
<td></td>
</tr>
<tr>
<td>ER&lt;sup&gt;-1&lt;/sup&gt;</td>
<td>.52</td>
<td>.35</td>
<td>7.38</td>
<td>12.06</td>
<td></td>
</tr>
<tr>
<td>ER&lt;sup&gt;-2&lt;/sup&gt;</td>
<td>1.05</td>
<td>1.98</td>
<td>-.16</td>
<td>-11.97</td>
<td></td>
</tr>
<tr>
<td>D107</td>
<td>-.12</td>
<td>-.81</td>
<td>-1.83</td>
<td>-.44</td>
<td></td>
</tr>
<tr>
<td>D107ER&lt;sup&gt;-1&lt;/sup&gt;</td>
<td>10.47</td>
<td>.97</td>
<td>-5.59</td>
<td>-1.37</td>
<td></td>
</tr>
<tr>
<td>D107ER&lt;sup&gt;-2&lt;/sup&gt;</td>
<td>-.43</td>
<td>-.50</td>
<td>.27</td>
<td>1.68</td>
<td></td>
</tr>
<tr>
<td>D107P4</td>
<td>3.23</td>
<td>2.34</td>
<td>-.26</td>
<td>-.06</td>
<td></td>
</tr>
<tr>
<td>D108</td>
<td>-.70</td>
<td>-.64</td>
<td>-.52</td>
<td>-.18</td>
<td></td>
</tr>
<tr>
<td>D108ER&lt;sup&gt;-1&lt;/sup&gt;</td>
<td>12.11</td>
<td>.26</td>
<td>-13.17</td>
<td>-1.22</td>
<td></td>
</tr>
<tr>
<td>D108ER&lt;sup&gt;-2&lt;/sup&gt;</td>
<td>3.76</td>
<td>.02</td>
<td>15.22</td>
<td>2.32</td>
<td></td>
</tr>
<tr>
<td>D108P4</td>
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<td>1.80</td>
<td>.55</td>
<td>.19</td>
<td></td>
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<tr>
<td>D108P15</td>
<td>-.33</td>
<td>-.12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D111</td>
<td>.53</td>
<td>.24</td>
<td>-.99</td>
<td>-.51</td>
<td></td>
</tr>
<tr>
<td>D111ER&lt;sup&gt;-1&lt;/sup&gt;</td>
<td>.89</td>
<td>.11</td>
<td>.27</td>
<td>.03</td>
<td></td>
</tr>
<tr>
<td>D111ER&lt;sup&gt;-2&lt;/sup&gt;</td>
<td>4.51</td>
<td>.81</td>
<td>-.74</td>
<td>-.25</td>
<td></td>
</tr>
<tr>
<td>D111P4</td>
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<td>-.10</td>
<td></td>
<td></td>
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</tr>
<tr>
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<td>-.27</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D113</td>
<td>-1.33</td>
<td>-1.02</td>
<td>-.95</td>
<td>-.46</td>
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</tr>
<tr>
<td>D113ER&lt;sup&gt;-1&lt;/sup&gt;</td>
<td>16.81</td>
<td>1.74</td>
<td>-3.48</td>
<td>-.52</td>
<td></td>
</tr>
<tr>
<td>D113ER&lt;sup&gt;-2&lt;/sup&gt;</td>
<td>-11.77</td>
<td>-1.21</td>
<td>4.51</td>
<td>1.31</td>
<td></td>
</tr>
<tr>
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<td>-.34</td>
<td>1.12</td>
<td>.45</td>
<td></td>
</tr>
<tr>
<td>D113P15</td>
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<td>.39</td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>1.40</td>
<td>1.63</td>
<td>-3.21</td>
<td>-1.09</td>
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</tr>
<tr>
<td>D114ER&lt;sup&gt;-1&lt;/sup&gt;</td>
<td>8.17</td>
<td>4.72</td>
<td>5.86</td>
<td>2.49</td>
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<tr>
<td>D114ER&lt;sup&gt;-2&lt;/sup&gt;</td>
<td>-.75</td>
<td>-1.37</td>
<td>-.37</td>
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<tr>
<td>D114P4</td>
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<td>.56</td>
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<td></td>
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<tr>
<td>D114P15</td>
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<tr>
<td>D115</td>
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<tr>
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<td>-19.66</td>
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<tr>
<td>D115ER&lt;sup&gt;-2&lt;/sup&gt;</td>
<td>46.82</td>
<td>2.55</td>
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<tr>
<td>D115P4</td>
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<td>.55</td>
<td>.82</td>
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</table>
regions 111, 113 and 116. Prices significantly different at the .01 level characterized regions 114, 115 and 122, while 107 and 108 were at .05.

Terracing is used on soils whose prices differ significantly from those where permanent vegetative cover is employed. However, the difference in soil prices where permanent vegetative cover or conservation tillage practices were used is not statistically significant.

It would be possible to calculate implicit soil prices at all levels of erosion for each region-practice combination and trace out a curve in dollar-erosion rate space. The envelope of all such curves would represent the highest value of soil savings at a given erosion rate. The highest point on the envelope curve would be a point on a particular region practice curve and would represent the value of soil savings gained from using the practice in that region on soils eroding at the indicated rate. Successively lesser-valued soils are saved by moving down the curve. Administrators of soil conservation programs could focus efforts on the most highly-valued soils using the best practice.

Such a process is not likely to be followed for several reasons. First, it is politically infeasible. Such an approach would eliminate cost sharing in broad areas—a practice not likely to be approved by Congress. Second, the accuracy of the data is suspect due to the aggregation of practices and soils within regions. The accuracy is insufficient to justify such hairline targeting.

As an alternative, the estimates of the implicit soil prices by
region can be found for given prepractice erosion rates using the coefficients in Table 11. These can be ranked to see which region has the least (most) valuable soil on average. The rankings vary little up to 10 tons/acre. Calculating the implicit price of a ton of soil at an erosion rate of 5 tons leads to the regional rankings by practice presented below.

For permanent vegetative cover practices, implicit soil prices from low to high order the regions as

\[
\begin{align*}
115 & \quad 122 & \quad 116=109 & \quad 107=108=111 & \quad 113 & \quad 114 & \quad (1975-1978) \\
107 & \quad 108 & \quad 114=115 & \quad 113 & \quad 116 & \quad 111 & \quad 109 & \quad 122 & \quad (1981-1982).
\end{align*}
\]

For terracing, it is

\[
\begin{align*}
115 & \quad 109 & \quad 113 & \quad 114 & \quad 108 & \quad 107 & \quad (1975-1978) \\
109 & \quad 107 & \quad 115 & \quad 108 & \quad 111 & \quad 116 & \quad 113 & \quad 114 & \quad 122 & \quad (1981-1982).
\end{align*}
\]

The conservation tillage practice was used only in the latter period. The regional ranking is

\[
\begin{align*}
108 & \quad 111=109 & \quad 113 & \quad 114 & \quad (1981-1982).
\end{align*}
\]

Although the rankings vary somewhat by practices and between time periods, there is sufficient similarity to conclude that soils saved in regions 111, 113 and 114 are most valuable while those in 115 are among the least valuable. To the extent that the ACP evaluation and resulting program changes reflect increased efficiency of conservation fund usage, more weight may be given the latter period values. The policy
significance of these results is presented in more detail in the next section.

Policy Implications and Limitations

The efforts of physical scientists have increased public awareness of the extent of the erosion problem. However, the increased awareness has been limited to knowledge of the amount of soil moving. Moving soil has been considered "lost" even though the soil is usually still in use further down the slope. It has also been assumed that all soils are equally valuable. Therefore, targeting efforts have focused on the most erosive soils.

Economic criteria suggest that funds should be used in such a way as to get the greatest possible benefit from the last dollar spent. Although conservationists have focused on increasing the cost effectiveness of conservation programs, cost effectiveness has been in terms of tons of soil saved per dollar. This is an improvement over random or broad-based spending patterns but still does not accord with what is economically optimal. An optimal decision rule requires marginal costs to be equated to marginal benefits with benefits and costs measured in comparable units. Recent efforts to assess productivity losses due to erosion (conservation benefits) have attempted to do this by measuring the amount of soil moving and then estimating the impacts of such movements on crop yields. While additional research of this variety is needed, this is not the only approach to the problem. In fact, changes in prices may render moot the impact of erosion on yields given present
technologies since new methods will likely be innovated to economize on scarce factors. An alternate method of measuring costs associated with erosion is to examine how much farmers are willing to pay to stop it. This research proposes such a measure. It is shown that benefits are not constant over all regions.

Areas with abundant soil or less productive soils are generally areas of lower soil conservation prices, whereas areas with highly productive thin soils or soils that are erosive and more productive but moderately thick have higher conservation values. If a ton of soil conservation could be achieved at equal cost, the higher-valued areas should receive the subsidies.

To the extent that benefit measures derived above are accurate, these results suggest that federal funding of soil conservation practices should not be subject to pork barrel allocation methods, nor should it be based on gross soil erosion estimates. Rather, a truly cost effective program would target funds to areas losing the most productivity. When the area of interest is the Corn Belt, major land resource area 115 is not a high priority area, while areas 111, 113 and 114 are. Conservation assistance to farmers in major land resource areas 111, 113 and 114 will secure more benefits than targeting to other areas even though erosion is more severe elsewhere. The economic criteria thus suggest that serious erosion problem areas need not be the areas with the greatest amount of erosion.

It was hypothesized that within the state of Iowa, the focus of conservation efforts would be in the south central counties (MLRA 109)
where soil is thin, yet marginal productivity is high. Although erosion in terms of tons of soil moving is greatest in western Iowa (MLRA 107), the greatest conservation benefits accrue to a ton of soil saved in the thin-soiled areas. The evidence on this hypothesis was mixed so that a clear conclusion was not forthcoming.

A similar analysis could be performed for other regions and states. State and federal committees and agencies responsible for allocating conservation assistance funds would then have some basis on which to make funding decisions. Funding of projects in particular areas could be justified so that present broad-based funding could be cut back more easily. Programs such as the Conservation Technical Assistance program could more accurately target funds using this methodology and hopefully withstand political pressure that seems to be turning this targeting program into another broad-based 'fund a bit everywhere' program.

If the justification of conservation spending is to reduce the impact of erosion on productivity, then the approach outlined above can be usefully applied to discover where productivity losses are greatest. In the areas examined here, relative prices of soils were roughly the same from both social and private points of view so that targeting on the basis of productivity losses satisfies the societal optima. Where significant differences in offsite costs exist, productivity values may be offset so that targeting based on societal prices differs from that based on private productivity based prices.

The existence of analytical problems prohibits the above approach from being the sole provider of information for targeting decisions.
Nevertheless, the insights gained would appear to be significant in improving present conservation funding methods.
CHAPTER VI. THE ADOPTION OF CONSERVATION PRACTICES

The analysis above provides insight into where conservation funds should be invested. This chapter focuses on factors related to the decision of which practice to use given that conservation occurs.

A number of studies have attempted to model the adoption process associated with conservation practice usage. The goal has usually been to understand characteristics associated with adopters (or constraints imposed on nonadopters) so that policy changes can be made to increase program effectiveness. As noted in Chapter III, the idea of targeting soil conservation efforts to achieve the maximum amount of benefits has typically focused on increasing conservation on those soils where erosion is greatest. An alternative economic criterion discussed in Chapters IV and V suggests focusing on those soils with the largest conservation benefits in terms of productivity saved. A method of determining conservation benefits was proposed and applied to soils in the Corn Belt and in Iowa. However, given the voluntary nature of present government programs, farmers in specific areas or with certain characteristics may be more likely than others to engage in erosion control. Government subsidies or aid might be targeted to such individuals. This reasoning accounts for the criteria in the CTA program mentioned earlier which considers willingness of farmers to participate in the determination of where to target investment funds. Researchers have hypothesized that certain factors affect the adoption decision; then proceeded to empirically test such hypotheses (Ervin and Ervin, 50; Miranowski et al., 91; Boron, 15; Lee and Stewart, 79).
Previous studies examining the adoption decision have not considered the choice among practices once a decision to adopt has been made.

Previous conservation practice adoption studies are reviewed in this section. It is shown that the seemingly ad hoc nature of the studies can be traced to a theoretical foundation. That theory and the relevant estimation procedures are discussed. A model is developed to examine the effect of physical characteristics on the decision of which soil conservation practice to adopt given that adoption occurs. The results of applying the model to the 1981-1982 Corn Belt data described above are presented and policy implications are briefly reviewed.

Previous Studies

Ervin and Ervin (50) provide a review of previous research, then incorporate hypotheses from earlier studies into an integrated model. They use an ordinary least squares estimation technique to measure the effect of various personal, institutional, economic and physical factors on a farmer's perception of erosion problems, his decision to use conservation practices, and the amount of soil conservation effort undertaken. The study uses sample data from a Missouri county. Three equations corresponding to the perception, decision and effort components above were estimated. Perception of a problem was hypothesized to be positively correlated with erosion potential (KLS), education, a conservation attitude index, a farm orientation index, and whether or not a farmer was an SCS cooperator, had a farm conservation plan or farmed
in an organized watershed. No economic factors were considered. The decision to use a conservation practice and the level of effort were represented by the number of practices used and the difference between the farm erosion rate with conservation practices and the farm erosion rate without such practices. These variables were regressed on all of the dependent variables from the perception model as well as on percent of land receiving cost sharing, the percent of income due to off farm sources, a debt concern index, a risk aversion index, total cropland farmed, and dummy variables representing (1) an intention to transfer the farm to a child and (2) cash grain operations. Despite the large number of variables, only 25-30 percent of the variability of the dependent variables was explained. Erosion potential, education, the risk aversion index, the cash grain farm dummy, and the cost share variables were significant at the .10 level.

The Ervin and Ervin model has a number of problems. The dependent variables are proxies of questionable nature and so-called economic factors are not represented by economic variables. Some qualitative information is forthcoming, but no quantitative measures are developed. The study does note that SCS cooperation, farm conservation plans and organized watersheds are not significantly associated with increases in any of the three dependent variables.

Miranowski et al. (91) estimated a linear probability model using survey data from an Iowa watershed. The probability that a farmer uses a primary tillage practice other than moldboard plow was hypothesized to be a positive function of education, experience, tenure status, crop
rotations, and field type (slope). The probability of adoption was hypothesized to be negatively related to changes in yields and risk. The effect of farm size was a priori unknown. A great deal of variability was unexplained by the model, but some interesting results were obtained. While most variables had the expected sign, farm size was found to be negatively correlated with adoption. Education and field type were quite significant while the risk variable was not. The incorporation of risk using farmers' perceptions of yield differences associated with practices and the inherent riskiness of tillage practices was novel. However, the small number of observations limited statistical analysis.

Boron (15) used a logit model to identify differences in land ownership characteristics between farmers who invested in soil conservation and farmers who did not. His analysis focused on farmers in four regions of the central United States and considered tenure status, amount of land farmed, land value, owner's age and level of education and net farm income. He hypothesized that (1) owners who operate part or all of their land are more likely to invest in conservation than owners who rent out all of their land; (2) landlords who use share rental leases are more likely to invest in conservation than landlords who use cash rental leases; and (3) the amount of land farmed, land value, and net farm income are positively linked to adoption but that age has a negative value. The model was applied to each region separately. While results vary somewhat by region, the probability of investment in conservation practices was positively correlated with education and acres
owned and negatively correlated with age. In three of the four regions, including the Corn Belt, owners who operated part of their land or used share leases on land rented out were much more likely to invest in conservation than owners using only cash leases. Boron did not measure the extent of adoption, nor was conservation practice well-defined. Farmers were considered adopters if they answered affirmatively when asked if they invested in conservation practices 'such as terraces, grass waterways, or gully control'. While region specific estimation was performed, there was no attempt to verify whether regional differences were sufficient to justify such a procedure. Additionally, there was no attempt to hold erosivity constant, which may invalidate most of his results.

Lee and Stewart (79) used a logit model to estimate the proportion of farms with specified characteristics that adopted minimum tillage. Characteristics considered included tenure status, farm size, erosion potential, region and organizational structure. They found that full owner operators and land owners with small holdings have lower adoption rates than other groups. Organizational structure had no significant impact. Regional effects were the most important factors explaining minimum tillage adoption. Again, no quantitative measures of the importance of explanatory variables were forthcoming. Furthermore, minimum tillage was considered in the absence of any other conservation practice.
Theoretical Basis of Adoption Models

The above models and other adoption models are often perceived as being ad hoc and resting on no theoretical foundation (Ervin and Ervin, 50; Feder, 51). The lack of formal models is not surprising given the nature of the problem. However, it can be shown that a formal model does underlie such efforts. The adoption process is a problem of choice under conditions of uncertainty. Such a portfolio selection problem can be solved given the farmer's utility function (embodying risk preferences), his choices and accompanying constraints, and the domain and distribution of future events (Miranowski et al., 91). This economic model of individual behavior allows calculation of optimal amounts of consumption and production by households and firms when a continuum of choices is available. Researchers have assumed a profit maximizer exists that selects practices based on costs and returns. Average population behavior can be derived from a random sample of individuals in such a programming approach. Policy changes influencing adoption can be modeled directly so that quantitative measures of erosion control are forthcoming. However, the data on individual utility functions and risk preferences required to perform such analyses are not available. Hypothetical situations can be modeled but the results may be of dubious value to policy makers.

When data requirements of the programming method are not met or when choices are discrete, population behavior can be described only in probabilistic terms. The econometric problem becomes one of modeling the selection probabilities, then determining the implications for
choice. This is the basis for the above models. Statistical analysis relates the conditional probability of a particular choice to attributes of the alternatives and/or characteristics of decision makers (Judge et al., 72). In this case, the direction of the effect of policy changes is usually all that can be determined. The magnitude of any changes is generally unknown. Two problems remain: (1) what statistical methods are available? and (2) what attributes or characteristics should be included as explanatory variables?

Statistical methods

The adoption studies reviewed above use various statistical techniques to link attributes to decisions and derive the associated probabilities. Usually adoption is viewed as an either-or decision. A farmer either adopts a particular practice or he does not. While the rate of adoption may be modeled using a linear probability model, the dichotomous nature of the dependent variable leads to problems of heteroscedasticity and the possibility that predictions may not make sense (outside a 0-1 range). If few or only one observation per setting of the independent variables are available, it is not possible to correct for heteroscedasticity. This is the case when continuous explanatory variables are used. The simple logit model overcomes these problems at some expense. The technique estimates the log of the odds that a particular choice is made using a maximum likelihood approach. However, if a farmer can choose among several alternatives, the simple logit model is also inappropriate because probabilities are
not constrained to sum to one. Two other statistical techniques exist which can be used—the multinomial logit and the multinomial probit. The multinomial logit approach assumes that alternatives are independent. The odds of a particular dichotomous choice must be unaffected as additional alternatives are added (Judge et al., 72). If alternatives are close substitutes, this assumption may be violated. The multinomial probit does not have this limitation. However, it has been used little due to computational difficulties. Although recent efforts have developed computational procedures, it is more expensive than multinomial logit and the additional benefits derived are questionable (Judge et al., 72). The adoption of conservation practices is modeled below with the multinomial logit approach because (1) one observation per setting rules out linear probability; (2) multiple choices eliminate the simple logit model; and (3) a multinomial logit procedure was obtainable at low cost and differences in results from multinomial logit and probit models have been small in past studies (Judge et al., 72).

**Explanatory variables**

McFadden (87) has derived the multinomial, or what he terms the conditional logit model in a utility maximization framework. Following McFadden, let $X$ denote the universe of choices, and $A$ the universe of measured attributes associated with decision makers. A randomly selected individual will face some subset of choices $C \subseteq X$ and will have an attribute vector $a \in A$. Let $P(x|a,C)$ be the conditional probability that $x$ is chosen given $a$ and $C$. Define a model of individual behavior as a set of rules $R$ with $r$ being an individual behavior rule describing a choice
in C given a. If \( R \) describes a population, then there exists a probability \( p \) which specifies the distribution of behavior rules in the population. The probability that an individual drawn at random will choose \( x \) given \( a \) and \( C \) equals the probability of the occurrence of a decision rule yielding this choice (McFadden, 87). That is

\[
P(x|a,C) = p[\{r \in R \mid r(a,C) = x\}]. \quad (62a)
\]

Let an individual's utility function be represented by

\[
U = V(a,x) + e(a,x) \quad (62b)
\]

where \( V \) is nonstochastic and reflects representative tastes of the population. The term \( e \) is stochastic and reflects individual taste peculiarities. The probability that an individual utility maximizer drawn at random from the population will choose \( x_i \) is

\[
P_i = P_i(x|a,C) = p[\{r \in R \mid r(a,C) = x_i\}] \quad (63)
\]

\[
= p\{(e(a,x_j) - e(a,x_i) < v(a,x_i) - v(a,x_j) \text{ for all } j \neq i\}.
\]

There exists, then, a joint cumulative distribution function

\[
F(e_1, \ldots, e_j) = p[\{r \in R \mid e(a,x_j) < e \text{ for } j = 1, \ldots, J\}]. \quad (64)
\]

Let \( F_i \) be the partial derivative of \( F \) with respect to its \( i \)th argument and let \( V_i = V(a,x_i) \). Then, equation 63 becomes

\[
P_i = \int_{e=\infty}^{\infty} F_i(e + V_i - V_1, \ldots, e + V_i - V_j) \, de. \quad (65)
\]
If alternatives are independent

\[ P(y|a, (x,y))/P(x|a, (x,y)) = P(y|a,C)/P(x|a,C) \quad . \]  

(59)

That is, the odds of \( y \) being chosen over \( x \) in a multiple choice situation \( C \) equals the odds of a binary choice of \( y \) over \( x \). Assuming

\[ P(x|a,C) \geq 0 \text{ letting } p_{xy} = P(x|a,(x,y)), p_{yx}/p_{xy} = (P_{yz}/P_{zy}) \quad \text{and} \]

\[ V(a,x,z) = \log(P_{xz}/P_{zx}) \text{ where } z \text{ is a reference member of } C, \text{ then it} \]

can be shown (McFadden, 87) that

\[ P(x|a,C) = \exp[v(a,x,z)]/\sum_{y \in C} \exp[v(y,z,z)] \quad . \]  

(60)

If \( V(a,x,z) = v(a,x) - v(a,z) \), then equation 60 becomes

\[ P(x|a,C) = \exp[v(a,x)]/\sum_{y \in C} \exp[v(a,y)] \quad . \]  

(61)

McFadden shows that if the error terms in equation 55 are independently and identically distributed with the Weibull density function, then the selection probabilities in equation 58 satisfy equation 61. If \( v(a,x) \) is linear, then

\[ P_{ij} = P(x_i|a_j,C_j) = \exp(\sum_{j=1}^{J} B_{ij})/ \sum_{j=1}^{J} \exp(\sum_{j=1}^{J} B_{ij}) \quad . \]  

(62)

The probability of individual \( i \) choosing alternative \( j \) is related to a vector of observations on variables that are functions of the attributes and/or the individuals \( (Z_{ij}') \) and an unknown parameter vector \( B \) to be estimated. When explanatory variables have differential impacts upon the odds of choosing one alternative over another, \( B \) is alternative specific. The log odds of alternative \( j \) relative to alternative \( i \)
is

\[
\log\left[ \frac{P_{ij}}{P_{il}} \right] = \log\left[ \frac{\exp(Z'_{ij}B_j)}{\exp(Z'_{il}B_i)} \right]
= Z'_{ij}(B_j - B_i) .
\]

Selection probabilities are

\[
P_{il} = \frac{1}{1 + \sum_{j=2}^{J} \exp(Z'_{ij}B_j)}
\]
\[
P_{ij} = \frac{\exp(Z'_{ij}B_j)}{1 + \sum_{j=2}^{J} \exp(Z'_{ij}B_j)} .
\]

Maximum likelihood estimators of the parameters in equation 71 are efficient and normally distributed allowing normal hypothesis testing (McFadden).

This model has been applied in studies of travel demand, occupational choice, and college attendance among others (Judge et al., 72; Maddala, 83).

The Choice Among Practices

The determination of which practice to use once a decision to adopt a conservation practice has been made can be modeled using the above approach.

The model is made operational by hypothesizing that various soil characteristics affect a farmer's decision to adopt a specific conservation practice. Differences in soil characteristics can be accounted for in several ways. One method would be to differentiate soils by major land resource areas as in Chapter V. Lee and Stewart (79) found that regional differences account for significant differences in the
adoption rate of minimum tillage. However, they considered the Corn Belt as one region. The emphasis on targeting requires a smaller delineation of regions.

In addition to broad regional differences, adoption rates will likely vary within regions with soil characteristics. Intraregion differences in soil characteristics are incorporated by considering differences in soil classifications, slope, and prepractice erosion rates. Structural and social variables hypothesized by others to affect the adoption decision will likely be important in the choice of practice too. Although such variables are missing from the model, physical characteristics are likely to account for some of these differences across farmers. Since the primary concern is with soil characteristics, only limited attempts to include structural characteristics were made. Since data on farm size were available in the data set, this variable was included. It is possible that farm size picks up a number of other social characteristics—income, risk, credit constraints, experience and education (Feder, 51; Miranowski et al., 91). The percentage of the practice costs paid for by government was also included to assess the effects of policy on the choice of which practice to use.

Thus, the Z vector in equation 69 includes regional dummies for the MLRAs. The effect of these variables on relative adoption rates is a priori unknown. Four variables for farm size are used due to the fact that farm size is reported in discrete form. \( F1 \) is 1 if farm acreage is less than 100 acres, and 0 otherwise. Similarly, \( F2 \) represents farms of 101-300 acres, and \( F3 \) denotes farm size of 301-500
acres. F4 is excluded to avoid perfect collinearity and represents farms larger than 500 acres. Miranowski et al. (91) found farm size to be negatively correlated with nonconventional tillage adoption while Boron (15) and Lee and Stewart (79) found a positive relationship. It can be argued that larger farms allow a farmer to have access to better information. Operators of larger units would therefore be aware of profitable practices and leaders in their adoption. However, the impact of tax policy may mitigate this advantage if the practice is capital intensive. Davenport et al. (44) suggest that this occurs. Large farms may be less likely to adopt terracing than small farms, and more likely to adopt the other practices than are small farms due to tax incentives. The delineation between small and large is not known and the effect of farm size on adoption is uncertain.

Three land class variables are used to differentiate soils on the basis of productivity. L1 and L2 are dummy variables taking the value of 1 if soils are in a certain class and 0 otherwise. L1 includes class I and class II soils. Classes III and IV are in L2. Soils in classes VI and VII are in L3, the excluded variable. L1 might be expected to be highly correlated with conservation tillage and less so with terracing and permanent vegetative cover since erosion is not a limiting factor to production on soils in this category. L2 is expected to be highly correlated with terracing while L3 is hypothesized to be significantly linked to permanent vegetative cover practices.

In addition to the discrete variables, two continuous variables further differentiating soil characteristics are used—slope (S) and
prepractice erosion rate (B4L). It is hypothesized that slope and pre-practice erosion rates are positively related to the adoption of terracing and permanent vegetative cover but less important in conservation tillage adoption.

The percent of practice cost borne by government (PCT) is included to assess the differential effect of subsidies on practice adoption. Thus, Z'B can be written as

\[ a + B_1D107 + B_2D108 + B_3D109 + B_4D111 + B_5D113 + B_6D114 + B_7D115 + B_8D116 + \ldots + B_{19}F1 + B_{10}F2 + B_{11}F3 + B_{12}L1 + B_{13}L2 + B_{14}S + B_{15}B4L + B_{16}PCT \]  

The constant term includes the excluded variables D122, F4, and L3. The various regional, farm size and soil class variable coefficients are therefore measures of the differences between the means of that category and the excluded variables.

Estimation of the parameters in equation 72 was carried out by maximum likelihood methods. The likelihood function is

\[ L = \prod_{i=1}^{M} \frac{1}{\pi} \prod_{j=1}^{J} \frac{\exp(Z_i'B_j)}{\sum_{j=2}^{J} \exp(Z_i'B_j)} \]  

where M is the number of observations and J is the number of alternatives (Judge et al., 1972). A computer routine using an unconstrained nonlinear optimization procedure, the Newton-Raphson algorithm, was applied. The results are in the form of equation 70, the log odds of one alternative relative to another, and are shown in Table 12.

The results show that practice adoption varies by region, land
Table 12. Estimates of coefficients and t ratios<sup>a</sup>

<table>
<thead>
<tr>
<th>Independent variables</th>
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<th>ln(P&lt;sub&gt;1&lt;/sub&gt;/P&lt;sub&gt;4&lt;/sub&gt;)</th>
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<sup>a</sup>Coefficient divided by asymptotic standard error.

<sup>b</sup>P<sub>1</sub> - permanent vegetative cover establishment
P<sub>2</sub> - permanent vegetative cover improvement
P<sub>4</sub> - terracing
P<sub>15</sub> - conservation tillage.
class, farm size and, to a degree, by prepractice erosion rate. The coefficient columns show the effect of the independent variables on the likelihood of adopting practice \( i \) over practice \( j \). The estimation procedure derives estimates of the asymptotic standard errors which are used to calculate 't-ratios' and can be used in hypothesis testing. Positive coefficients favor adoption of \( P_i \) while negative coefficients increase the likelihood of \( P_j \). For example, in the third column (\( P_1/P_4 \)), other things being equal, the likelihood of adopting permanent vegetative cover establishment compared to terracing increases in regions 111 and 114 but decreases in 107, 108, 109 and 115 from that in 122. Similarly, if a soil is in land class 3 or 4 (L2), it increases the likelihood that terracing will be chosen over permanent vegetative cover establishment. The effect is in the same direction but of a greater magnitude for soils in land classes 1 and 2 (L1). Note the effect of farm size—the larger the farm, the more likely terracing will be chosen. The cost share, slope and erosion rate variables are insignificant although in this case (\( P_1/P_4 \)) the signs are as expected. Slope and erosion rate have a negative impact and subsidies have a positive effect on the likelihood of adopting terracing over permanent vegetative cover. The cost share and slope variables are, in fact, insignificant in all equations. The effect of slope may already be picked up in the erosion rate and soil class variables. Since the sample is composed only of subsidized adopters, and variation in subsidy rates has been very small, it may not be surprising that the cost share variable has little effect on the choice of practice decision.
An analogous interpretation can be made for each equation corresponding to a column of coefficients. An alternative method of examining the results would be to consider the ordering of practices given an independent variable. Consider the land class variable L2. Soils in this class increase the likelihood of adopting terraces over all other practices. The adoption of conservation tillage is more likely than the adoption of either of the permanent vegetative cover practices on soils in this class. The results are similar for L1 but the effect is even greater. Thus, the likelihood of adopting terracing and conservation tillage is greatest on the better soils holding all other variables constant.

Examination of the farm size variables in a similar fashion reveals that the smallest farms (F1) are more likely to adopt a permanent vegetative cover practice over conservation tillage, and conservation tillage over terracing. Farms in the 100-300 acre category (F2) are most likely to adopt terracing and least likely to adopt conservation tillage. On farms of 300-500 acres, the ordering from most to least likely becomes terracing, establishing permanent vegetative cover, conservation tillage and improving permanent vegetative cover. The erosion rate variable increases the likelihood of adopting conservation tillage over permanent vegetative cover and permanent vegetative cover over terracing when other factors are constant.

A similar analysis could be carried out for each region. Alternatively, the estimated probabilities can be calculated using equation 71 and recalling that the estimated probabilities must sum to one. The
estimated probabilities or adoption rates are shown in Table 13 for the various farm size and land class combinations. Calculations were performed near the means of the continuous variables (PCT = .5, S = 8, B4L = 10).

It is obvious that particular practices are most likely to be adopted in particular areas—terracing in regions 107, 109, and 115; conservation tillage in 108, 111, 114, and 116; and permanent vegetative cover in 113, 116 and 122.

Since the decision here is which practice to adopt rather than whether or not to adopt any practice, comparison of results with other studies is limited. However, these results do extend the finding of Lee and Stewart that regional effects are important determinants of conservation practice adoption. While their results were for broad geographic groupings and minimum tillage only, similar results were obtained here for smaller areas and the choice among conservation practices. Similarly, the findings of Miranowski et al. (91) and Lee and Stewart (79) that erosion potential and field type are important determinants of conservation practice adoption are extended. Land class and erosion rate are significant determinants of which practice is adopted given that adoption occurs. While effects differ by region, the better land classes are associated with larger rates of adoption of terracing and conservation tillage. The more erosive soils are linked to higher rates of conservation tillage adoption. This latter result would be expected up to a limit but continues throughout, which is troubling. Examination of the data reveals that while the great majority
Table 13. Probability of adoption of soil conservation practices by region for land class and farm size combinations

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**Conservation Tillage**

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of observations are on land eroding at less than 15 tons per acre per year, several very large erosion rates (>600) are included. Surprisingly, conservation tillage is the practice used on these soils. This may be sufficient to yield the results above. While Lee and Stewart (79) found farm size to be positively associated with minimum tillage adoption, Miranowski et al. (91) found a negative relationship. The results here indicate that farm size is a significant determinant of which practice is adopted. Smaller farms are likely to have adoption patterns which differ from larger farms.

Farmers of small tracts are less likely to adopt minimum tillage than are larger farmers—a finding which tends to support the results obtained by Lee and Stewart. However, results do not allow a complete comparison since only adopters are considered here. Indeed, smaller farms are likely to be associated with higher rates of adoption of permanent vegetative cover than are larger farms. The net result could be a higher or lower rate of adoption of conservation practices in general.

Policy Implications and Limitations

If the adoption of particular practices is desired, then several policy implications arise from these findings. Expanded use of conservation practices can be obtained by focusing on particular major land resource areas. Permanent vegetative cover practices are most likely to be adopted on the rolling hills of western Iowa, southern Iowa, northern Missouri, and the Central Mississippi Valley (MLRAs 107,
Conservation tillage is the preferred practice in central Iowa and Illinois, Indiana and Ohio, where soils are gently sloping and cropland predominates. Increased use of conservation practices will likely follow these patterns. Attempting to increase the usage in a cross compliance program or a best management practice may not be an effective use of funds. The practices, as shown in Chapter V, are linked with the value of productivity being saved so that constraints on which practice is to be used may result in less valuable soils being conserved.

Within a given region, the adoption rate can be increased or decreased by focusing on operators with particular soil classes and farm sizes. In general, soils in the better land classes are more likely to be associated with adoption of terracing and conservation tillage and less likely to be treated with permanent vegetative cover practices. Farmers with small farms (i.e., less than 100 acres) are less likely to adopt terracing or conservation tillage and more likely to use permanent vegetative cover practices than are those with larger farms. Expanded use of terracing or conservation tillage will require that larger subsidies be given to those with small farms and poorer soils than those with larger farms and/or better soils if equal rates of adoption are desired.

Increases in the prepractice erosion rate increase the likelihood of choosing conservation tillage over the other practices and increases the probability of adopting permanent vegetative cover practices over terracing. Evidently, terracing is not viewed as an efficient control measure on the more erosive soils. These results may be somewhat biased
due to a few observations on extremely erosive soils.

The model results indicate that cost sharing has not had a significant impact on which practice is used. Wider variation of subsidy rates would be required to increase usage of particular practices on this basis.

Thus, the differences in adoption rates due to regional effects (land use, climate, topography, soil groups), soil classes, farm size and erosion rate provide policy makers with the opportunity to enhance program effectiveness by modifying the approach depending on characteristics of the target group.

However, the extent of adoption in the adoption model is uncertain. The probability of adopting a particular practice in a particular area may be quite small but given that adoption occurs, the practice may be applied to a large number of acres. Therefore, targeting funds here may be as effective as making funds available in an area where the probability of adoption is greater but less area is covered.

The model above examines the adoption decision as a function of a limited number of variables. Undoubtedly the decision is based on factors other than those in the model—most of which are linked to soil characteristics. Education, experience, tenure status, risk attitudes and income are all likely to play a part in the decision-making process. The bias associated with excluded variables depends upon their correlation with the included variables. Some bias is therefore likely.

If more information was available on nonadopters, then it would be possible to more thoroughly model the adoption decision using a limited
dependent variable technique such as Tobit analysis. In the absence of such information, it might be possible to extend the present analysis to analyze determinants of soil savings given adoption of particular practices.
CHAPTER VII. SUMMARY AND CONCLUSIONS

The purpose of this study has been to examine the efficiency with which investments in soil conservation are made. The efficiency issue includes the determination of the proper role of government, the optimal amount of conservation and an accurate measure of conservation benefits. The determination of which conservation practice is most beneficial is also required. This chapter includes a brief summary of the most important points developed in the research and the attendant conclusions.

Justification of the Research

Chapter II contains a review of the literature of soil formation, soil erosion, and soil conservation. The literature indicates that while soil formation does occur, much remains to be learned about the process. Recent advances in measuring techniques, such as the Universal Soil Loss and Wind Erosion Equations, have increased awareness of the magnitude of soil movement but significant gaps in our knowledge of soil loss remain. Furthermore, the impact of changes in the soil resource on soil productivity is not yet well-understood. Present tolerable levels of erosion (T-values) are based on a few, dated, unreliable assumptions.

Nevertheless, government has been involved in soil conservation efforts, using the measurement techniques and the T-values presently available as the basis for policy decisions. The proper role of government is not easily determined since both allocative and distributive questions are involved. Welfare economics suggests that the pareto
efficiency criterion be used. Although the value judgments required are not easily defended, the efficiency concept is useful in policy analysis and can be used in conjunction with soil conservation policy.

The possible reasons government might wish to invest in soil conservation arise from market failures leading to inefficient resource use. Externalities, inadequate markets or constraints on individuals can give rise to inefficient use of the soil resource. Government programs ostensibly remedy such market failures but are not without problems. Analysis of government conservation programs has shown the need to increase their effectiveness. Constraints on government conservation funds have also forced policy makers to consider how best to use the available funds. A recent suggestion to improve governmental efforts is to target funds to critical areas. The determination of critical areas has been based on such criteria as the amount and extent of soil loss, the expected results, willingness of farmers to participate in a program, the effect of erosion on productivity, off-site damages, and other social and economic conditions. The severity of erosion as measured in tons per acre per year has dominated and become the major determinant of which areas receive targeting funds. Program evaluations have used this same measure to assess cost effectiveness. Such an approach assumes all soils are equally productive and yield equal amounts of offsite damages. One ton of soil is the same as any other ton. Since this is not likely to be the case, there is a need for economic criteria to determine which areas should receive scarce conservation funds.
The need for a more accurate measure of erosion-induced damages is apparent. Current research has taken several tracks. One approach has been to estimate the amount of soil leaving the field at current erosion rates, extrapolate the amount into the future, and then determine the amount of soil left at the end of the period and its productive potential. A comparison with present production levels shows the reduction in yields expected. A second, relatively recent, method attempts to relate soil characteristics to yields, then shows how yields change as erosion alters soil characteristics. Both methods have focused attention on the consequences of soil movement and provide information which could be used to develop a measure of productivity loss if particular crops grow in specific areas for a lengthy period of time. However, more adequate economic criteria can be developed to guide targeting efforts. The criteria are developed in an economic model and allow valuing the benefits of conservation. Empirical results from Iowa and the Corn Belt are used to show the differences in soil conservation values and the implications for targeting.

The Economic Model and its Application

Optimal decision rules for soil use are initially developed from a static profit maximizing model. The economic rationale for targeting requires funds be invested in those inputs (practices) where the marginal value product to input price ratio is the greatest. The difference in societal and private optima is shown to be a measure of market failure. An intertemporal model is then developed to include the effects of time since erosion in the present has effects on future
time periods. Dynamic optima are different from static results since effects on future time periods must be considered. When soil erosion and conservation practices are considered, optimality requires the marginal cost of the practice be equal to the marginal benefits from reduced erosion. Measures of marginal costs and marginal products are calculated for a sample of Corn Belt farmers and are used to estimate implicit soil prices. The difference between societal and private prices is interpreted as a measure of the offsite costs of erosion. It is shown that implicit soil prices are measures of the value of soil productivity at the margin. These prices decrease with the erosion rate and vary across regions. Areas with abundant soil or low productive soils generally have the lowest soil values. Higher soil values are associated with areas of highly productive thin soils or moderately thick and erosive soils. The calculated soil values can be used on a state, regional or national level to improve the efficiency with which conservation investments are made by targeting such investments to areas with the largest returns per dollar spent.

The choice of which conservation practice to adopt was examined for insights into further methods of improving targeting. Past studies have considered the adopt-not adopt decision without developing the theoretical foundation for such models. The underlying choice theory and estimation procedures are examined. Given that adoption occurs, the choice of practice used is related to regional, soil class, farm size, and erosion rate characteristics. The findings regarding the effects of these variables on choice reinforce the findings of previous
studies. Region and farm size were previously found to affect the adopt-not adopt decision and are found to also be important determinants of which practice is used given adoption. Smaller farms adopt less capital intensive practices. Terracing and conservation tillage are more likely to be used on the better land. Cost sharing was not found to be a significant determinant of choice. The results suggest that increased use of particular practices can be obtained by focusing on farms of a particular size with specific soil classes and in certain areas. If cost sharing is to be a determinant of practice usage, a wider variation in subsidy levels is necessary. Attempting to increase the level of usage of a particular practice in a region may not be an effective use of funds if the practice is not readily adopted on soils in that area. Best management practices and cross compliance requirements should thus be chosen with care.

Conclusions and Future Research Efforts

This study has shown that economic criteria can be used to increase the efficiency with which government conservation investments are made. It is also possible to find measures of conservation benefits. The use of economic criteria provides policy makers with information necessary to target conservation assistance to particular areas and withstand political pressures that dilute program effectiveness. While the information is useful, a few caveats are in order.

The implicit soil values obtained in the empirical analysis are based on the assumption that farmers are economically rational. A
farmer who adopts conservation practices that are uneconomical because he believes it is the right thing to do would lead to over-valuation of the soil. Similarly, if farmers fail to invest in sufficient conservation, the implicit prices are underestimates of conservation benefits. If a large number of one type of farmer lives in a particular area, the results obtained above will be biased.

Policy recommendations are based on the value of soil in agricultural production. The results indicate that relative values of soils in different areas are the same from both social and private points of view—at least in the region considered. Other regions might have variations in offsite costs which offset productivity values so that targeting based on societal values differs from that based on private values.

The adoption model does not consider the extent of adoption but only the likelihood a practice is chosen. Although the likelihood may be small, if the area treated is quite large, then subsidizing such a practice may be as effective as subsidizing a practice that has a higher probability of adoption but is used on a smaller area.

Finally, the results are based on a sample of conservation practice users who receive government subsidies. The results may be generalized to other such users, but if those not receiving subsidies differ significantly from the sample group, the results may not hold for the entire population. Additionally, the nature of the sample may mean results cannot be generalized to the major land resource areas as done here.

Several issues can be considered further in light of this research.
The scope of the study could be broadened to determine implicit conservation prices in other parts of the United States. Where accurate measures of offsite costs due to agricultural related soil erosion are available, such information could be compared to the estimates arising in the model. The size of subsidy could then be evaluated.

It would also be possible to use the procedure developed here to estimate implicit prices of other unpriced or inaccurately priced resources. Irrigation water would be such a resource. Policy implications regarding the efficiency of government funding of water projects would be forthcoming.

The choice of practice modeling is relevant to the adoption of other agriculture technologies that are not simultaneously linked to yet other practices. Such an approach might be used to examine the effect of various farmer characteristics on the choice of the type of tractor to purchase, the kind of irrigation technology to employ, or the selection of a financial institution with which to do business.


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